

MARCH 2008

tunnels & tunnelling INTERNATIONAL

FOCUS ON DRILL & BLAST

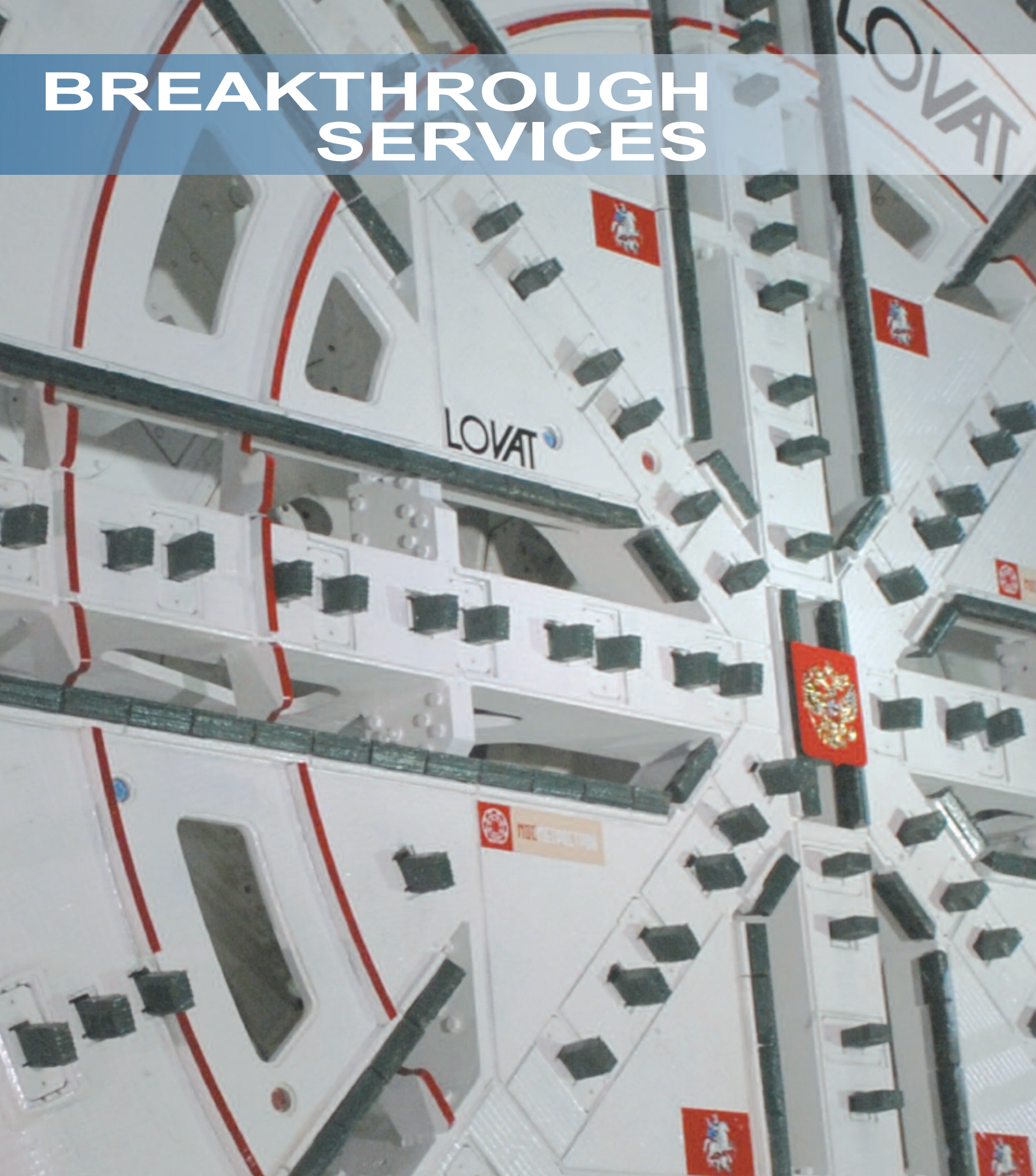
This month's focus includes a report on early experiences with electronic blasting in Korea

SPRAYED CONCRETE

T&TI looks at tunnel lining methods involving shotcrete



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Contents

FRONT COVER:
A Murphy engineer inspects the completed 4.15m i.d. National Grid tunnel on the Lower Lea Valley Cable Tunnel Project, in London (p34).

WEB ADDRESS
www.tunnelsonline.info

CONVERSIONS
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5 COMMENT

6 WORLD NEWS

12 BUSINESS & FINANCE

FOCUS ON DRILL & BLAST

15 FINLAND DRILL & BLAST

Servicing Helsinki's underground city
A new underground service tunnel is being built in Helsinki to remove commercial supply traffic from the city's historic centre

18 BLASTING TECHNOLOGY

Electronic blasting in Korea
Research into electronic blasting systems used on a drill and blast rail tunnel in Korea

22 HYDROPOWER TUNNELS

Looking at tunnel roughness
Research at the Karahnjúkar Hydropower project in Iceland is being used to assist tunnel roughness and headloss estimation

15

Drill and blast operations underway under Helsinki

27 CONTRACT LAW

Global Claims
T&T looks at what is meant by a Global Claim and some new common law developments



30 OBITUARIES

32 PRODUCTS & SERVICES

34 BRITISH TUNNELLING SOCIETY

Lower Lea Valley Cable Tunnels
A review of the history and construction of the UK's Lower Lea cable tunnels built to house power lines ahead of the Olympics

22

Surveying tunnel wall roughness at Karahnjúkar

SPRAYED CONCRETE

39 SHOTCRETE TECHNOLOGY

Sprayed concrete success
T&T looks at some recent developments in the occasionally controversial field of sprayed concrete

43 CLASSIFIED ADVERTISEMENTS

45 DATES & EVENTS



18

Electronic blasting research undertaken in Korea





SCOTLAND: BREAKTHROUGH FOR NESSI'S HYDROPOWER.

Britain's most efficient hydropower plant is being built at the world-famous Loch Ness in the Scottish Highlands. With 100 megawatts, it will produce sufficient power to provide 250,000 people with environmentally-friendly electricity. The power plant is located in a cavern below the south eastern lake shore and is supplied with water from a reservoir through a tunnel that is almost 8 kilometers long.

In September 2006, the Herrenknecht S-351, a Gripper TBM with a diameter of 5.03 meters and the name "Eliza Jane" took up tunnelling with a gradient of up to 12 percent. The TBM cut through the hard rock with best weekly performances of up to 270 meters negotiating altitude differences of 600 meters. A top tunnelling performance which helped to bring the project rapidly to completion: On January 7, 2008 the machine reached its target ahead of schedule.

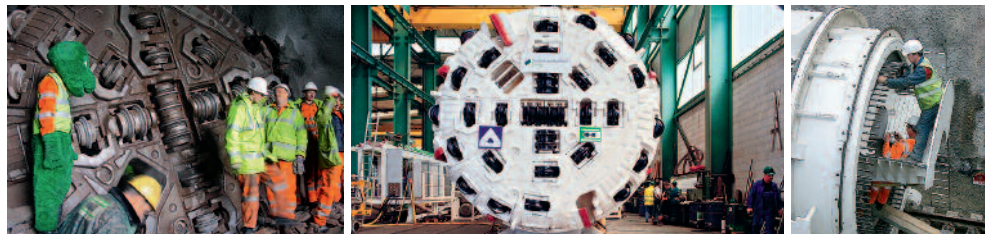
GLENDOE | BRITAIN

PROJECT DATA

 S-351
 1x Gripper TBM
 Diameter: 5,030mm
 Driving power: 2,200kW
 Tunnel length: 7,750m
 Geology: hard rock

CONTRACTOR

Hochtief
 Construction AG



A strategy for the future

think it's high time we as an industry took a long hard look at how we tout for trade, if indeed we do. Generally speaking, projects come up via a client's need, whether it's a transport solution, power provision, or maybe a water supply/quality hurdle that has to be overcome. There, we've already hit our first potential hurdle before we've begun.

Basically the clients have to come to us. The problem is, some clients probably don't even think about the underground option, possibly precluding our skill base from the word go.

But let's assume the better case scenario that our client is tunnel savvy and is prepared to go underground. We then individually get our heads down and tender for the project whereupon, in a competitive bid, the client will generally choose the lowest bidder. The next stage is for the lucky winner to get in and build the tunnel, hopefully to a reasonable profit, in an adversary-free (as possible) fashion, before heading back into the shadows to wait for the next project to come up.

Not particularly pro-active is it?

Now turn this completely on its head. Why don't you go and look for the problem, there are plenty there, design and price the solution, then tout it to the relevant client. Go to them, why wait for them to come to you! And why stop

there? Take it a step further and find ways to help prove the funding is viable. Barrack local businesses, property developers, politicians, the local community, anyone who will benefit in the long term from your solution. Explain the benefits in a solid business plan, pointing out the social costing and how expense now will turn to profit in the future.

Maybe it's time to bring back more of the entrepreneurial spirit into civil engineering as displayed by the historical giants such as Brunel and Stevenson, who simply wouldn't let opportunity pass them by. Isambard Brunel wrote in his diaries that he wanted to be, "the first engineer and an example to future ones", he also saw opportunity everywhere and even feared losing out saying, "what a field, yet I may miss it!"

How many of us in this modern age genuinely fear missing future opportunities or chances of innovation, as opposed to fear losing a current tender?

By waiting for clients to come to us when a problem needs to be fixed, instead of actively proving to them that we can help before the problem gets out of hand, I fear there may be many wonderful chances missed in our particular field.

Tris Thomas



COMPANIES IN THIS ISSUE

Aarau	10	Continental Engineering	8	HongLim Co	20	Mott MacDonald	22, 36	Sando Construcciones	10
ADIF	10	Cowi	7	Impregilo	22	Mowlem	12	Sandvik	16, 17
Air Control	32	Coyne et Bellier	22	Irishenco	12	MTR Corp	8	Sembawang	6
Almenna Consulting	22	CSC	10	Ital Thai Developments	8	MTRC	11	Shanghai Urban	8
Alpine Mayreder	8	Daewoo	7	ITD CEM	8	MWH	22	Construction	8
AlpTransit	10	Delhi Metro Rail Corp	8	J Murphy & Sons	34, 36	National Grid	34, 35, 36	Shimizu	6
Alwag	41	DHV	12	John Holland	11	NFM Technologies	7	Soares da Costa	12
Amberg	39, 42	Dogus	10	Kawasaki	6	Nishimatsu	12	Soletance Bachy	6
Amec	12	DSI	41	KBR	34	Norconsult	22	Soma Enterprises	8
Arup	11, 34	Dywidag International	8	Kumagai	11	Normet	17	Spie Batignolles	12
Balfour Beatty	11, 32	EDF Energy	34, 35	Landsvirkjun	22, 24	OeBB	32	SRV Vittoset	15
BASF	32, 39	Edmund Nuttall	12	Larsen & Toubro	8	Orica Mining Services	18	Struckton	7
Bechtel	11	Elta Fans	32	Leighton Contractors	11	OtB Engineering	7	Sweco	22
Bekaert	41	Faber Maunsell	34, 35	Lemminkäinen Infra	15, 17	Pantex	41	Synhydro Engineering	
Carl von Gehlen	32	FCC Construcción	10	Liebherr	42	Parsons Brinckerhoff	34, 35	Bureau	7
Cerida Consulting	7	Fjarhitun	22	Lienhard+Cie	10	Plus 3 Consultants	27	Systra	11
CH2M Hill	7	Frutiger	10	Linuhonun	22	Pöyry	22, 23, 24	Taisei	6
Charcon	35	Gammon Construction	6	Lovat	10, 12, 37	Rafteikning	22	TEC	7
China Railway Tunnel Group		Geoeng Consultants	6	Lugano	10	Rede Ferroviaria Nacional		Tehri Hydro Development	12
CIFA	42	Gim Tian Civil Engineering	6	Mapei	39	REFER	12	Thames Water	7
CMC Ravena	7	Gulermak	10	Maunsell	6, 8	Rescon Mapei	17	Thun	10
Comet	32	Halcrow	7, 11	Meinhardt Infrastructure	6	Robbins	8, 10, 22	Tubelines	36
Consortio Monte Ceneri	10	Hanwha Corp	18, 20	Mergor Engineering	7	Rothpletz	10	Tunnelling	7
Construcciones Sanchez		Herrenknecht	8, 10, 11, 41	Meyco Equipment	32, 39, 42	Rowa	32	UCL	36
Domiunguez-Sando	10	Hindustan Construction	8	Mitsubishi Heavy Industries	8	Saanio & Riekkola	15	VST Consulting	22, 24
		Hnit	22	Morgan Est	10, 12	Samsung	6, 8	WJ Groundwater	35

Singapore's latest Circle Line breakthroughs ...



Second hole through at Botanical Gardens, Circle Line, Singapore

granite, soft residual soils and significant sections of mixed face conditions. Cover ranged from 20m-25m through residential areas and under transport links and utilities. The next drives will negotiate an area of piled foundations and the Deep Tunnel Sewer with 1.8m clearance.

Each TBM has nominal torque of 3120kNm, 1500kW drive power and 43,000kN thrust. The operating slurry face pressures generally equated to 20kPa over pore water pressure and consequent volume losses were approximately 0.5% and surface settlement were about 5mm-15mm, said Samuel Adair McChesney, project manager for Singapore Government's metro developer Land Transport Authority (LTA), which is supervising the works directly.

With a cut diameter of 6.72m, the TBMs are building a segmental bolted lining (5+1) that is 275mm thick and sealed with gaskets. McChesney said the lining performed 'extremely well' with negligible cracking, spalling or leakage.

In December, two identical shields – TBMs 1 & 2 – completed successive 1.1km long eastbound drives to Thomson and Marymount stations after being launched from Bukit Brown in February and May 2006, respectively. The lead machine, TBM1, achieved 19m/week and TBM2 advanced on average 24m/week. The shields have been stripped out and the skins left in place.

In February, Taisei's second Kawasaki TBM holed through at Botanical Gardens station on Phase 4 of the Circle Line (CCL) project – a month after the first 6.63m diameter slurry machine.

The shields, TBMs 4 & 3, respectively, were launched from Bukit Brown on 2,269m westbound drives to Botanical Gardens station in June 2006, and the average weekly rates were 26.5m on 24-hour operation for each. They are being refurbished for relaunch on the final, twin 900m long mixed faced drives to Farrer station.

Geology along the route of contract C854 comprises fresh

... while Downtown Line starts up

Construction on Singapore metro's new Downtown Line Phase I works started last month, and the major tunnelling work is being undertaken by Shimizu in a US\$74.5M contract.

The main tunnelling contract (C905) for the 4.3km underground line involves design and construction of the tunnels between Promenade station and Marina Bay. Shimizu beat four rival bidders last year for the contract. Supervising firm is Maunsell Consultants (Singapore).

Further tunnelling works will take place under separate contracts for station construction at Bayfront, Landmark, Cross Street and Chinatown. The Phase I works are to be finished by 2013.

The Landmark contract (C907) is being executed by Taisei while the supervisor is Geoeng Consultants. Bayfront station (C906) was awarded to Sembawang Engineers & Constructors, with Gim Tian Civil Engineering as supervisor. Cross St is being designed and built (C908)

by a JV of Samsung and Soletanche Bachy. The Chinatown station contract (C909) is being undertaken by Gammon Construction. The supervisor for both jobs is Meinhardt Infrastructure.

The Singapore Government also recently signalled S\$20bn (US\$14.5bn) plans for extensions and additions to the metro network, including extending the North-South and the East-West lines by 1km and 14km, respectively. It will build two further

lines – Thomson (TSL) and Eastern Region (ERL), adding 48km to the network. The TSL is to be built by 2018 and ERL by 2020.

Separately, construction is continuing for the 12km long Kallang-Paya Lebar Expressway (KLE), 9km of which will be underground - the longest road tunnel in south east Asia, the government said. The 3km long tunnel in Phase I opened last October and the remainder will be finished this year.

Korea immersed tube placement underway



Float-out of first element of Busan-Geoje immersed tube



following contractor Daewoo Engineering & Construction's successful placement of the first 180m long section in mid-February.

In total, 18 elements each weighing up 48,000 tonnes will be cast in the Anjeong drydock, towed 36km and during a 40-hour long immersion process be placed on a prepared seabed trench in

about 15m-50m depth of water. There are 16 ordinary elements comprised of eight 22.5m long segments (1m thick walls; cross section of approximately 26.5m wide by 10m high) and two special elements.

The 3.2km long tube will be the deepest immersed road tunnel in the world, said Danish consultant Cowi which has designed the permanent works and some temporary works for the tube as part of joint venture work with Daewoo Engineering Co.

The contractor is being supported further by a joint venture of Tunnel Engineering Consultants (TEC) of the Netherlands, which is advising, and Halcrow.

The crossing is part of a 8.2km long link between the mainland port city of Busan and the island of Geoje. Design work on the US\$5.8bn fixed link project began in 2003 and the project is scheduled for completion in 2010.

Float out of elements will only happen in winter due to sea

swells, and towing takes 10 hours. The offshore conditions are harsh and never been seen before for an immersed tube, said the design JV. A further key challenge has been preparing the dredged trench foundation by improving the stiffness of the soft marine clays, which have low unit weight in comparison to the load from the tunnel and rock cover for scour protection.

Following the immersion of the second element, Cowi anticipates that another one or two elements will be placed this winter season. The remaining elements are to be placed over two more winter seasons – 2008/9 and 2009/10.

Four elements were cast in the first batch in the drydock in Jinhae Bay for placing this season, and a further four elements are to be completed in drydock in June. Afterwards, there will be two more batches each of five elements.

The immersion is executed by Dutch subcontractor Strukton Afzinktechnieken, operating as Mergor Underwater Engineering.

The second, 180m long element of the Busan-Geoje immersed tube road tunnel in South Korea was due to be towed into position late March

NFM bags China TBM orders

NFM Technologies has been awarded contracts totalling US\$25.2M to supply two TBMs for the Yintao water diversion project at Tahoe river in China.

The 5.75m hard rock shields have been ordered by China Railway Tunnel Group Co (CRTGC) and Chinese-Italian joint venture of CMC Ravenna and Synhydro Engineering Bureau.

CRTGC has order a single shield machine (named "T7") and the JV a telescopic shield ("T9"), and NFM said in February that

the TBMs are to be delivered within 11 months. They are to drive tunnels of 17.2km and 18.2km, respectively.

NFM said it has sold 15 machines in China in the last year and a half, and its order book stands at US\$205M.

Tahoe river is a tributary of the Yangtze and the diversion project is to convey water to Gansu province in north west China. The Yintao scheme started in 2006 and the TBMs will work on the first of two, six-year long project phases.

Tideway prog manager picked

US consultant CH2M Hill, supported by UK firms Halcrow and Tunnelling Ltd, has been appointed as programme manager for the Tideway sewer interceptor tunnel by Thames Water.

Construction of the project is expected to start next year with the 6.8km Lee Tunnel branch, which will intercept half of all overflows. The branch sewer is to be finished by 2014.

The main 32km long tunnel to be built mostly under the river Thames, however, is not expected to start construction until 2012. The 7.2m i.d. sewer is scheduled to be finished in 2020.

Thames Water will call on the programme management

team to assist from gaining planning consents and preliminary and detailed design through to construction oversight, commissioning and start-up of the facilities. The utility noted CH2M's experience on similar projects in the Singapore and Milwaukee, Wisconsin.

Halcrow has diverse experience in major tunnel projects. Tunnelling Ltd has been formed by individuals with a wide range of experience in international projects.

The first-run geophysical survey of much of the Thames was completed in January by a joint venture of OtB Engineering and Cerida Consulting (T&T, February, p6).

Delhi metro Ph2 underway



Left: Two more TBMs lowered at the Delhi metro in February
Below: Earlier TBM assembly



Lowering of two further TBMs into the launch boxes at the Delhi metro last month has taken the total number of machines getting underway on Phase 2 of the project to four, and a further two are due in the ground next month.

Later this year another eight machines are to be launched on the latest stage of the metro project, and excavations by all 14 TBMs are due to be completed by or during 2009, *T&T* was told by client Delhi Metro Rail Corp (DMRC).

Last month, the first two of four shields to be used on contract BC-16 between Udyog Bhavan to

Green Park were lowered. The two 6.54m diameter Herrenknecht EPBMs (S-411, S-412) were lowered at the INA box and will drive twin 2km long bores.

Next month, two EPBMs from Robbins and Mitsubishi Heavy Industries (MHI) are due to be lowered at the site to drive a pair of tunnels of the same length in the opposite direction. All four machines were built in China.

Geology along alignment comprise sandy silt, silty sand and gravels. The groundwater level ranges from the surface to a depth of 20m. The cover to the tunnels is about 15m, and the EPBMs are to

work under 3 bar pressure. The segmental lining (5+1) has two internal diameters - 5.7m and 5.8m.

The contractor on BC-16 is a joint venture of Taiwanese firm Continental Engineering Corp (CEC) and local company Soma Enterprises. Just over a year ago, the JV was awarded a 40 month contract to design and construct the tunnels. In addition, the contractor is to build four stations - Race Course, Jor Bagh, INA and AllIMS - each 318m long.

For contract BC-18 (Hauz Khas-Malviya Nagar), which is being undertaken by Metro Tunnelling

Group (MTG), two TBMs were launched last December. Driving from Malviya Nagar, the 6.46m diameter Herrenknecht machines (S-403 and S-404) that were previously used in Phase 1 of Delhi metro will now excavate twin 3km long tunnels.

MTG is a Dywidag International-led JV and it was awarded its 38 month contract in early 2007. The JV members previously worked together on Phase 1 of the metro (*T&T*, February 2007, p7).

Machines to be launched later this year are: four TBMs on BC-24 by the JV of Ital Thai Developments (ITD) and ITD CEM; two TBMs on AMEL-C1 by the JV of Alpine, Hindustan Construction (HCC) and Samsung; and, two TBMs on AMEL-C5 by the JV of Shanghai Urban Construction (Group) Corp and Larsen & Toubro (L&T).

Maunsell gets HK's South Island Line

MTR Corp has appointed Maunsell Aecom as design consultant for its South Island Line (East) in Hong Kong, which will involve approximately 3.5km of tunnelled route.

The consultant has a nine month contract to work with the client to produce the most cost-effective design solution for the link and develop it to preliminary

design stage. The 7km long route also involves cut and cover tunnels as well as viaducts.

Work on the design contract began last month. Commercial terms of the contract were not disclosed.

South Island Line (E) has an estimated cost of more US\$900M and will run from South Horizons, via Lei Tung, Wong Chuk Hang

and Ocean Park, to the key interchange of Admiralty station.

The line will link the existing Tsuen Wan Line, the Island Line, the future Shatin-to-Central Line (at Admiralty station), and an interchange for the future South Island Line (West) will be at Wong Chuk Hang.

Maunsell Aecom's design will address interfacing the four lines

at Admiralty station as well as soft ground tunnelling needs at Nam Fung portal, some major faults, and urban excavation in addition to various site constraints. In addition, cavern excavation will be required at Lei Tung station.

Approval for the link was given by the Government of Hong Kong in December 2007.



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Ceneri adit bore underway



Robbins TBM ready to excavate adit for the Ceneri Base Tunnel

Excauation of the adit for the Ceneri Base Tunnel by a 9.7m diameter Robbins TBM started last month at Sigrino, Switzerland.

The 2.4km long adit is being driven to reach the mid launch points for the later twin bore excavations for the main running tunnels, the contracts for which

have yet to be awarded.

Geology along the adit alignment comprises schist, molasses and orthogneiss of UCS 30MPa-130MPa. Contractor Consorzio Monte Ceneri (CMC) JV was to have commenced excavation of the adit in the third quarter of this year but, along with construction of the installation caverns, the work is still

to last two years.

The main beam TBM was previously used, as 'TBM1', to excavate a 14.65km stretch of the 39.6km long headrace tunnel on the Karahnjukar hydropower project in Iceland. It was refurbished near Milan, increased in diameter from 7.6m and fitted with 19" cutters. Robbins designed new probe drills for the machine and said previously that no squeezing ground or significant inflows were expected (*T&T*, September 2007, p7).

The adit bore will terminate where it meets an existing exploratory tunnel. At the junction the installation caverns have been built, from where the main running tunnels will be driven and which will house concrete batching plant.

CMC JV consists of CSC, Lugano, Frutiger, Thun, Rothpletz, Lienhard+Cie, and Aarau.

The 15.4km long, twin main running tunnels are to be driven by drill and blast and TBM. The north end tunnels will be excavated as twin 8km long drill and blast drives, and the method will also be used for a pair of 1.8km long bores in the south section. The remaining, parallel 4km long tunnels in the south sections will be driven by TBM.

Client AlpTransit expects the Ceneri rail route to be operational by 2019. AlpTransit is also building the Gotthard Base Tunnel (*T&T*, February, p11).

Progress in Istanbul, Coslada and Croydon

With a breakthrough, launch and relaunch, Lovat has seen progress achieved in projects underway with a range of EPBMs in Istanbul, Spain and England.

In Istanbul, the Gulermak-Dogus JV holed through at Kirazli station with a 6.5m diameter mixed face machine (RME257SE Series 23100) on its 1.3km long drive on the metro contract.

Launched from Bagcilar station to drive through clays, silts and sands with EPB pressures up to 5bar, the machine achieved advance rates of 31m/day, 154m/week and 412m/month, respectively.

The JV previously excavated twin 2.95km tunnels on the metro terminating at Bagcilar

using the RME257E Series 17900. In total, Lovat has supplied the JV with three machines for work on the metro.

In Spain, local contractor Sando Construcciones has launched a refurbished 4.7m diameter EPBM in Coslada to bore a 2.25km long sewer tunnel through gypsum. The second, 1.4km bore will see the RMW185SE Series 20202 drive through silty sand and fractured gypsum.

The Lovat ME140SE Series 23000 machine being operated by UK contractor Morgan Est has started work on the second phase of the Croydon cable tunnel project in south London. Geology along the next 7km of excavation comprises fractured chalk with flint beds.

Engineer tutors for skills gap?

A skills transfer initiative in the UK has been launched calling on engineers, including tunnellers, to help bridge the knowledge gulf by taking on formal training roles in the education sector.

The tutor scheme has been launched by Lifelong Learning UK (LLUK) to encourage engineers to contribute to the Further Education (FE) sector.

Following last month's launch of the "Bridging the Skills Gap" report, the recruitment campaign hopes to build on a pilot scheme which trained construction professionals to teach in the

further education sector.

The call follows the recent launch of the TunnelSkills initiative to meet the challenges of resourcing forthcoming major tunnelling projects in London, such as Crossrail and Thames Tideway, and the southeast with more trained, experienced workers (*T&T*, December 2007, p12).

TunnelSkills is an organisation with the backing of the British Tunnelling Society (BTS), clients and ConstructionSkills, and plans to boost the numbers in the qualified tunnelling workforce.

Herrenknecht TBMs out at Kowloon



Cabrera BT

The 9.69m diameter Herrenknecht TBM on the Cabrera high speed rail tunnel project in Spain has holed through and is being prepared for the second run from mid-year.

Excavation started in July last year and the contractor, a joint venture of FCC Construcción and Construcciones Sanchez Domínguez-Sando, made good progress on the 6.2km long drive over six months. The double shield (S-373) holed through at the end of January.

Geology along the route in the Sierra de la Cabrera mountains comprised limestone and

dolomite. The TBM has a cutterhead power of 4900kW.

The 8.75m i.d. tunnel lining consists of seven segmental sections. Safety cross passages will be built at approximately every 400m to connect the rail running tunnels.

ADIF, the Spanish rail network company, is building the Cabrera twin tubes as part of the 11.2km section of the Siete Aguas-Bunol part of the high-speed network between Valencia and Madrid. The Cabrera running tunnels are each 7.25km long and mostly TBM-driven (*T&T*, January, p8).



First of the twin tunnels finished on the Cabrera high speed rail project

Longer stretches of soft ground have enabled the second drive of the Kowloon Southern Link tunnel, in Hong Kong, to be completed faster by the 7.99m diameter Herrenknecht slurry TBM and hole through in early March.

The challenge of the second, 1.17km long drive saw it weave below streets, then over and beside the first tunnel, further complicated at times by being only one diameter or less below the surface.

Further challenges on the second drive included crossing above two metro tunnels with approximately 1.7m clearance, and 2m below a box culvert that is connected to the harbour. Also,

there was only 6.4m of cover beneath a major road intersection.

The TBM was re-launched for the second drive in late September last year. It had holed through on the first drive in late June after being launched in November 2006.

Originally, it was anticipated that the twin tunnels would be completed by January this year and in the third quarter last year, prior to the launch of the second drive, the client said that the final breakthrough was then expected to be this month, which has been achieved.

The first drive had its own challenges, in particular a brief setback when there was compressed air loss and some ground settlement below Salisbury Road on, fortunately, the quiet early hours in the weekend. The TBM had been stationary for a compressed air intervention.

The drives have been completed by contractor Link200 JV, members of which are Leighton Contractors (Asia), Balfour Beatty, Kumagai and John Holland. Link200 JV's US\$258M contract is one part of the US\$1.06bn project for hook-up the East and West metro lines.

Client for the project is now Mass Transit Railway Corp (MTRC), which took on the project as part of its takeover of Kowloon Canton Railway Corp (KCRC) last year.

HS-1 wins plaudit

The Channel Tunnel Rail Link has won a plaudit of "Project of the Decade" from the London Transport Awards.

Arup, a key player behind the UK project, renamed 'High Speed 1' (HS-1), is currently putting its own resources into exploring the possibilities for a second link, or HS-2, which could involve some major tunnelling works.

According to preliminary studies, the route might run from HS-1 to the north of London and on to Heathrow airport before heading northbound to the

Midlands and further. An initial report is expected in the next few months (*T&T*, January, p12).

The "Project of the Decade" award was received last month by Rail Link Engineering (RLE), which comprises Arup, Bechtel, Halcrow and Systra. RLE managed delivery of HS-1 for the developer, London & Continental Railways.

HS-1 fully opened late 2007. The 109km long route from the Channel Tunnel to London is the UK's first high-speed rail link and its first major railway for over a century. The scheme cost US\$11.6bn.

Dublin Port Tunnel JV sued over closures

The joint venture of Nishimatsu, Mowlem and Irishenco that built the Dublin Port Tunnel, opened just over a year ago, is being sued in a joint action by two Irish state bodies over alleged systems failures that have forced its closure four times in the last few months.

The consortium was officially notified near the end of February of the joint legal action being planned by two Irish state bodies, the National Roads Authority (NRA), which has overall responsibility for the structure, and Dublin City Council, which has charge of the contract.

The state bodies said in a letter that despite repeated assurances received about the tunnel systems there had been "a number of significant equipment malfunctions" since the handover

of the tunnel, just over a year ago. They claim that the consortium has failed to remedy them.

The letter, sent 27 February, added: "We put you on notice that we are taking legal action to recover all the costs arising from deficiencies in the equipment that you have provided."

The tunnel closures, in one case for a full day, caused traffic chaos across Dublin, forcing heavy trucks back on to the streets, and seriously disrupting business.

There was no comment from the JV concerning the threatened legal action, which will have to be resolved in the Irish High Court if a behind-the-scenes settlement is not reached.

The consortium is still seeking

Portugal's Refer awards Trofa tunnel

A contract to build a new rail tunnel and associated works on the Minho line in Portugal has been awarded to a joint venture of Soares da Costa and Spie Batignolles.

The value of the contract is just over US\$24.2M, excluding VAT, which is 23.7% less than the client, the country's national rail network company Rede Ferroviaria Nacional REFER's initial estimated budget of approximately US\$31.8M.

REFER received seven competitive bids for the new rail tunnel, which is to be built within 730 days. The tender process started in early 2007 and was announced last month. Project management and construction supervision is to be provided by DHV under a contract of US\$1.85M.

The tunnel is part of a 3,555m long branch section to be built at the town of Trofa, and under a separate contract a bridge and other associated works are to be built. The contract required the design and construction of a 1,404m long rail tunnel as well as associated surface works, cut and fill, and also reinforced concrete structures.

Trofa is some 20km along the rail line inland from Porto.

payments from Dublin City Council of up to US\$154M for completion of the 4.5km tunnel. The claim, which is disputed, is still in arbitration.

Dublin Port Tunnel was opened at the end of 2006. The twin tunnels were built by 2.6km bores

and the balance in cut and cover. Work started on the toll tunnel project in 2001. The project was built to take most HGVs travelling to and from the port off the roads, and within minutes be on the city's outer roads (*T&T*, January 2007, p10).

Tunnel work at Vishnugad Pipalkoti

The call for prequalification for the contract involving major tunnelling works to build the Vishnugad Pipalkoti hydro project in India has been rescheduled to the end of this month.

Tunnel works involved in the engineer, procurement and construction (EPC) contract include a 13.4km long by 8.8m wide headrace tunnel, a 130m high by 20m wide surge shaft and a 3.1km long tailrace tunnel. The underground powerhouse consists of two parts – the machine cavern (127m by 20.3m by 50m) and transformer cavern (112m by 16m by 24.5m).

The client, Tehri Hydro Development Corporation (THDC), plans to shortlist contractors. The developer estimates total civils costs at US\$355M, including dam construction.

Vishnugad Pipalkoti is to be a 444MW plant built in steep terrain on the Alaknanda river in the state of Uttarakhand.



Morgan Est helps boost parent's results

Morgan Est's tunnel contract wins last year helped boost parent Morgan Sindall's pre-tax profits and revenues for the year to 31 December 2007. The company's tunnels unit is also in the process of consolidating with the formal rival section within the Amec group. The division was part of Amec's DPS division, bought from Amec group last year by Morgan Sindall. The merged tunnelling units are operating as Morgan Est (*T&T*, Sept 2007, p12).

Morgan Sindall posted pre-tax profits, before amortisation, up 30% to US\$124M for last year. Revenues were 41% higher at US\$4.2bn. The order book increased 30% to US\$8.6bn.

Prior to the tunnelling unit merger, the Morgan Est unit alone was anticipating revenues of at least US\$140M – almost double the previous year and slightly ahead of that of the Amec unit.

The expanded Morgan Est tunnelling unit is working on the Croydon cable tunnel, Belfast sewer, tube station upgrades at King's Cross and Shepherd's Bush. It is also working on the flood relief sewer at Ross-on-Wye, England, which is worth approximately US\$4.2M to the firm (see photo). The main contractor is Edmund Nuttall. The Lovat 101 TBM, will excavate a 385m long siphon of 2.1m i.d. between two 6m wide, 15m deep shafts, and work is due to finish mid-year.

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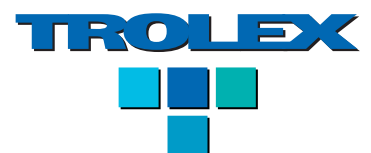
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Servicing Helsinki's 'Underground City'

The bedrock under Finland's capital city already accommodates a vast network of more than 400 tunnels and underground structures. These include everything from utility, water and metro tunnels, to underground shopping malls, parking and storage facilities, leisure complexes and of course Helsinki's famous Tempeliahaukio Church.

With an increasing demand for sustainable development and sound planning of land-use within the area's red and black granite, the City of Helsinki has decided to capitalise on future construction opportunities by formulating a strategic 'Underground City Plan'.

This plan is being used to manage the construction of a further 200 underground structures in forthcoming years, including new metro lines and an ambitious road tunnel project, which will connect existing access roads leading into the city.

The first stage of the City's long-term strategy is to extend and enhance the pedestrian surface area in the centre of the capital, by effectively removing all commercial supply traffic from the streets. This is being achieved via the construction of the US\$80M KEHU service tunnel project, which stretches 2.5km across the city from east to west (figure 1).

A long-term strategy for the future development of Helsinki's 'Underground City' includes a new service tunnel network, which is currently being constructed to remove commercial supply traffic from the surface of the historic city centre. Deputy editor, Amanda Foley, recently visited one of the contracts on the project

In June 2006, the City of Helsinki awarded a US\$34M lump sum fixed unit-price contract for excavation of the eastern section of the KEHU service tunnel to Helsinki-based contractor Lemminkäinen Infra (formerly Lemcon). Located in the commercial centre of the city, the contract includes a total of 1035m of drill and blast excavation and reinforcement works at depths of up to 35m, under some of the oldest buildings in the capital. Once completed, the tunnel will be used to service all the shops, restaurants, offices and hotels in the area. The contract forms part of a larger project for Lemminkäinen, who are also separately undertaking the construction of a new City Center service and parking parking cavern, as well as other storage structures and tunnel connections for the Kämp Hotel.

Kalliorakennus Corp is constructing the new Stockmann parking cavern, with SRV-Viitokset undertaking the remainder of the KEHU excavation works, including the new

Kamppi parking cavern and the City of Helsinki's other 1.5km long western tunnel contract, which will provide access to the new parking facilities.

Drill and blast works

Mobilising in July 2006, Lemminkäinen began by enlarging an existing underground civil defence shelter, on Vuorikatu, to create an entrance and point of attack at the eastern end of the tunnel alignment. Working two shifts, 6am-2pm and 2pm-10pm, good progress was achieved and at the beginning of 2007 a second face was

PROJECT FACTFILE

KEHU Service Tunnel

Client: City of Helsinki

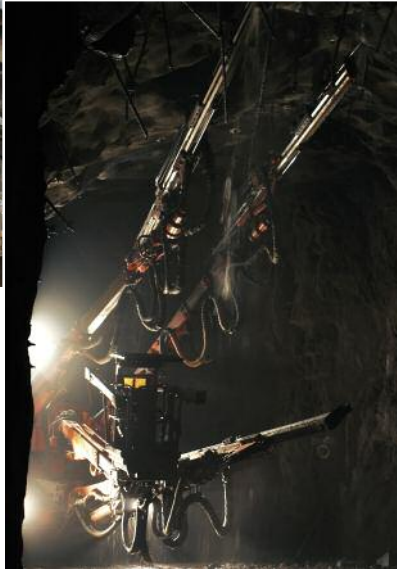
Design: Saanio & Riekkola Oy

Contractor: Lemminkäinen Infra (east section)
SRV Viitokset (west section)

Project duration: 2006-2010



Left and below: Lemminkäinen's Sandvik Tamrock Axera T11 drill rig in use under the centre of the city



opened up from another existing tunnel at Mikonkatu, midway along the project.

Automated drilling has been undertaken using a maximum of two Sandvik (Tamrock Axera) T11 3-boom rigs, with the number of holes drilled per round between 80 and 150. Round lengths vary from 2m to 6m depending upon the particular blast limits of each area. "The drill plan is continuously refined as we progress the drives," explains Marri Keskinen, development manager for Lemminkäinen. However, it is the rigs' computer that provides drilling accuracy. "Today operators have a great view of the face, but they don't really need it with automatic drilling, says Keskinen.

In order to reduce blast vibrations, Lemminkäinen has adopted a new method of controlling the delay times of the Nonel system. The previous system used by the contractor allowed just 25 different delays. Now, by combining the surface delays, 150

different delays can be created with the system. "Therefore we can blast more than 100 holes within the vibration limits," says Keskinen. In some of the more sensitive areas, where the settlement limit is just a few millimetres, the advance is also split into two faces.

At the time of T&T's site visit, at the end of last year, drill and blast operations were progressing well, with the contractor advancing one round per day on each of four faces. In the main, rock conditions had

been pretty much as expected, in the area's red and black granite. Due to the quantity of abrasive quartz in the rock, the Sandvik drill bits used were being changed about every 70m-80m.

Excavation challenges

Amongst the most significant challenges on the project, has been construction through the Kluuvi Cleft, a poor quality zone of gravels and clays that infringes upon the central section of the tunnel alignment.

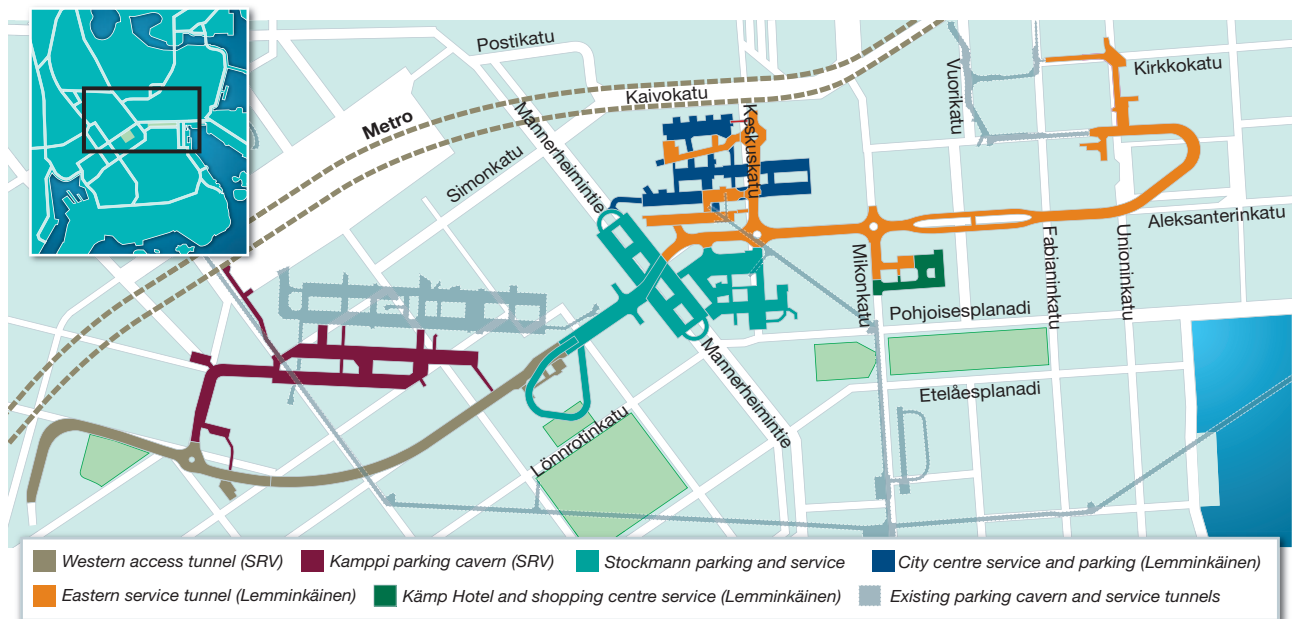
"Here the tunnel splits into two parallel tubes at that point, to avoid the worst of the zone," explains Keskinen. However, significant amounts of grouting, along with systematic rockbolting and wire mesh reinforced shotcrete have still been required in the area.

Another key issue has been the strict limitations on blast vibrations. As mentioned, there are numerous buildings located above the alignment. Many are extremely sensitive structures, such as the national art museum, the national library and the university. In addition, there are a number of sub-surface concerns, including the Helsinki Metro, which runs extremely close to the service tunnel (as near as 10m at one point).

During project planning, a risk analysis was undertaken for each individual structure, with vibration limits set for each accordingly (typically in the region of 10m/sec). In some areas acceleration values have also been specified, the smallest of which is 0.25g (or 5mm/second) close to an underground electrical equipment facility. The project team report that so far all of these limits have been met.

Under normal conditions Lemminkäinen is allowed to blast until 10pm. However, despite the late hour for such a residential

Fig 1: Map showing the current excavation works underway in the centre of Helsinki



area, this curfew is somewhat frustrating for the team. With the metro closed in the evenings higher vibration limits can be tolerated, offering a greater opportunity for advance. However, as the team gets near the closest point to the metro tunnels, it will be allowed to blast later into the night. "Most people who live in Helsinki are used to drill and blast works," says Keskinen. "For the last 30 years one contractor or another has been excavating here, so they are fairly used to the noise."

Groundwater lowering has been an additional concern during the works. Aged, and often rotten, wooden piles support many of the older buildings in the city, so it is vital that groundwater levels (generally 1m-2m from surface) are not affected during excavation. This has required extensive pre-grouting throughout the duration of the project.

Extension rods have been used to drill three rounds ahead of the face (approximately 24m) and cement grout, supplied by Rescon Mapei, injected. The leakage limits vary depending upon location, but are typically 2.5l/100m. The pre-grouting is reported to have been

highly successful so far, with the project team noting very little seepage.

Tunnel support & muck removal

Ranging from 1-7, the tunnel support installed is determined depending upon the rock class encountered. A minimum of 60mm of steel fibre reinforced shotcrete is specified for Type 1, with a maximum of 250mm of steel mesh reinforced shotcrete and systematic rockbolting (3m-4m long, 25mm diameter) for higher rock classes.

When T&T visited the project, Lemminkäinen reported shotcrete use had been slightly higher than expected, mainly due to the weakness of the rock around the Cleft. However, following scaling and installation of permanent drainage, typically a 80mm thick steel fibre reinforced shotcrete layer was being applied using a Normet rig.

Thanks to a centrally located custom underground concrete plant, with horizontal silos, material transports can be made outside of the city's rush hours, therefore it is not important if a transport is delayed. Another advantage of this set-up is that the plant is well away from the entrance of the tunnel during the harsh

temperatures of the winter months.

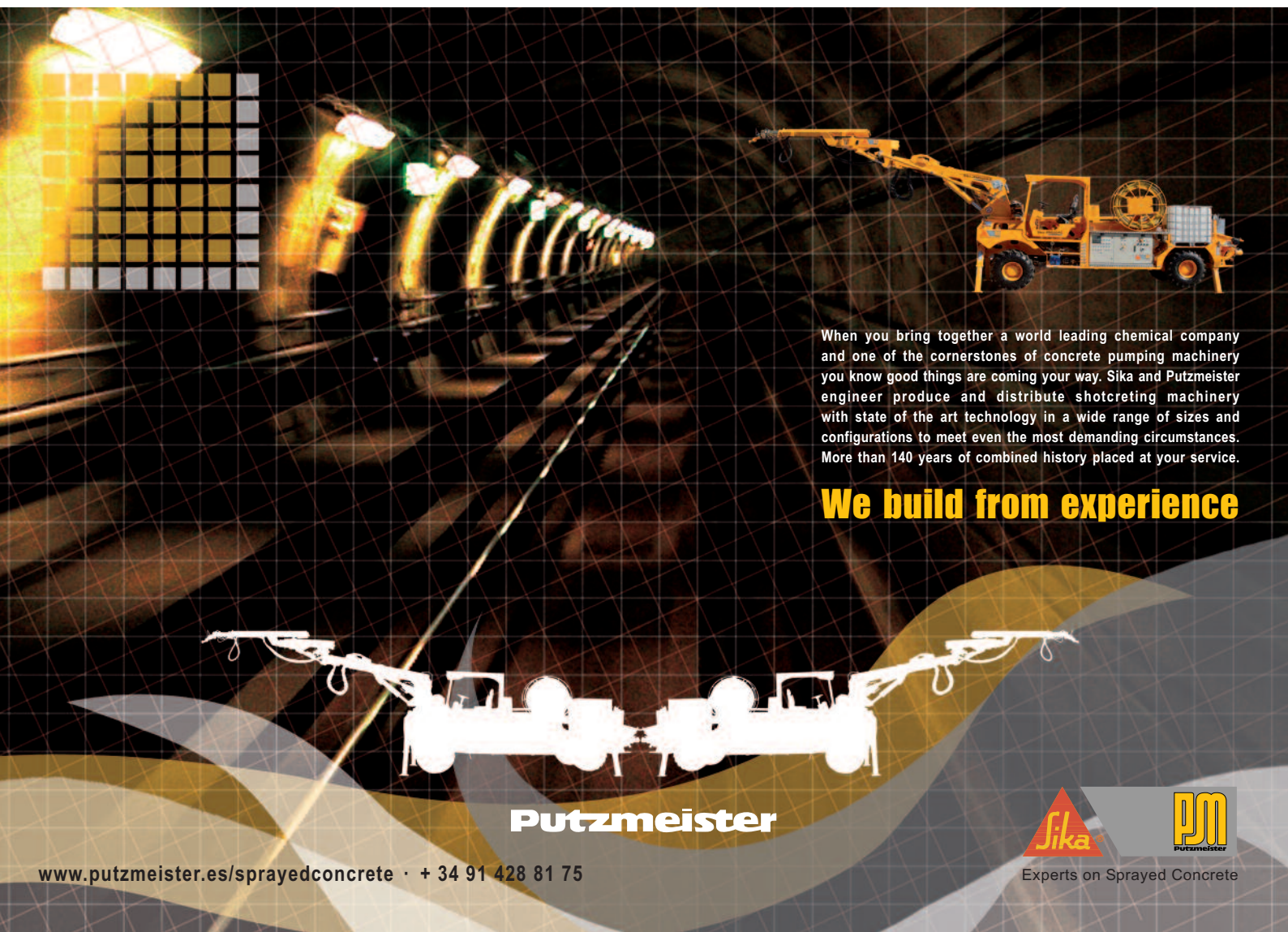
By the end of the drill and blast works, 170,000m³ of rock will have been excavated and transported to Helsinki's Vuosaari harbour redevelopment project, where it will be used mainly for building works. By the end of the project a total of 28,000 trips through the city centre to the harbour are expected, with about 6-10 trucks required per advance. Both mechanical scaling and rock transport is sub-contracted to a local firm.

Drill and blast works on Lemminkäinen's contract are now almost complete, well ahead of the July 2008 schedule. Other contractors will shortly commence casting of the concrete road deck, and installation of ventilation and M&E systems. The service tunnel is due to open to commercial trade in 2010.

T&T

ACKNOWLEDGMENTS

T&T would like to extend thanks to Sandvik Mining & Construction for organising this visit, and Lemminkäinen Infra's project team for its hospitality and assistance in preparing this article.



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Electronic blasting in Korea

David Kay, of Orica Mining Services, and Young-Suk Song, of the Hanwha Corporation's Commercial Explosives Division, describe here early experiences with electronic blasting systems in Korea



Above: The Kang Chon 1 Tunnel

South Korea is said to be one of the world's most mountainous countries with 70% of its landmass in rugged terrain. It also has one of the highest population densities in the world. To meet the needs of the growing population and industrial development, infrastructure projects are underway to improve transportation links between major population centres.

Given the predominant terrain and populous nature of the nation, preference is given to a 'straight line' method requiring significant use of tunnel and bridge for both road and rail construction. Granite and limestone rock are dominant, thereby making drill and blast the preferred method for tunnel advance.

One large-scale project underway is the Kyung-Chun Railway Line Construction that is providing a complete double track link between the South Korean city of Chuncheon and the capital of Seoul.

Opportunity arose to fire three 'full face' tunnel rounds in the Kang Chon 1 Tunnel of the 7th Zone of the Kyung-Chun Line using the i-kon Electronic Blasting System (EBS) and perform some preliminary assessment versus conventional pyrotechnic signal tube initiation. It also allowed for a fresh look at initiation timing possibilities for large civil

tunnels. This paper is a summary of the results obtained from a series of five firings in the Kang Chon 1 Tunnel - two preliminary bench marking blasts using conventional non-electric (NE) initiation followed by three firings by EBS and modified timings.

It should be noted that the results were obtained under 'production conditions' whereby data collection and trial quality were dictated by operational needs.

This paper will describe these limitations and attempts made to normalise the results to give performance indicators opposite key aspects of the tunnel cycle including: perimeter control, advance, fragmentation and vibration.

The Kang Chon 1 Tunnel

The Kang Chon 1 Tunnel is one of several on the 7th Section of the Kyang-Chun Line. The completed length will be 2500m with cross sectional dimensions of 10.6m wide by 8.4m high and a face area of 88m². The major rocks present are granite gneiss or banded gneiss with sporadic quartz dykes and scattered cubic jointing observed. A rock mass rating (RMR) gives a result of 66 indicating a medium hardness rock.

A 12-hour cycle is worked which includes: mark-up, drill, charge, fire, excavate, scale, bolt and shotcrete. Typical blasting parameters give 116 x 45mm diameter shotholes drilled with a V Cut (wedge), with a centre stab hole, for 3.5m round depth. Shotholes are charged with 32mm diameter emulsion cartridge explosives (MegaMITE) and stemmed with wet sand plugs. Perimeter holes are charged with a 17mm pipe charge (FINEX). Initiation uses a range of millisecond (20ms) and long period (100ms) non-electric detonators (HiNEL). To offset the timings the face is fired in 4 bunches which are fired with 0 to 42ms trunkline delays. A conventional face timing is shown in figure 1.

Electronic Initiation Design

Given the accuracy and flexibility of the electronic blasting system it was decided to redesign the face timing based on a number of good blasting principles. The V Cut timing was left the same as conventional, thus to minimise risk related to cut failure, giving three holes firing at any one instant.

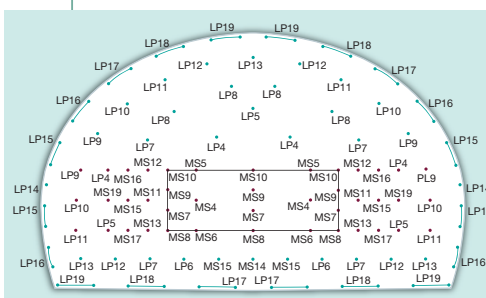
Once outside the V-Cut, timing was set to give single hole firing within 20ms, working in direct opposites from the initial cut. With the cut extension removed the face holes were set at 10ms, off-setting either side of centre. The perimeter was to be fired in 2 halves. One half was fired in instantaneous batches of 6 holes to gauge the effect of post-split perimeter control, while the other half was fired on 10ms delay interval.

The delay versus batch firing sides were swapped on alternate firings to negate the effect of geology. The lifter holes were designed to fire on 10ms delay offset either side of centre. Total blast duration was reduced from 3.2 seconds to 1.3 seconds (figure 2).

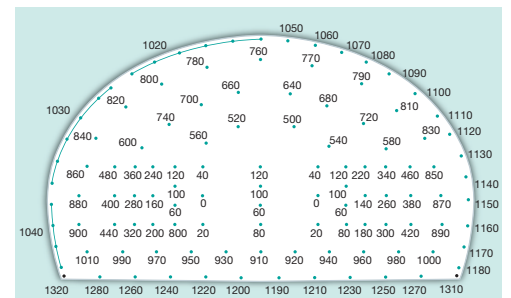
Tunnel conditions

During the evaluation period a porphyry intrusion entered the left-hand side of the tunnel face. This caused a number of poor

Below: Fig 1 – Conventional non-electronic timings with MS and LP series detonators



Below: Fig 2 – Generic electronic timing used in the blasts



Below: Change of rock quality in the face. The face is split almost vertically right down the middle, with the left hand side of the face in RMR = 47, and the right in RMR = 77



rounds both with the two non-electric blasts and the first electronic blast. The tunnel contractor decided to increase the number of shotholes drilled from 116 to 132. This change may have masked some results, however attempts were made to normalise the outcomes by swapping perimeter technique left and right and to compare results only in similar ground.

Vibration analysis

All blasts were monitored for vibration and airblast. Up to 4 monitors were used for each blast spaced along the tunnel at distances of 131m to 604m from the tunnel face. To give statistical credibility a further two non-electric blasts were included that were monitored the week previous (Table 1 and 2 and figures 3, 4, 5, 6).

Furthermore a comparison of the near field vibration traces was conducted. The available vibration recording time was only two seconds therefore latter stages of the non-electric blast is missing.

The following conclusions can be drawn from the above data:

Comparison of the regression analysis shows that both systems gave similar results

Below left: Fig 3 – Vibration trace electronic firing

Below right: Fig 4 – Vibration trace non-electronic firing

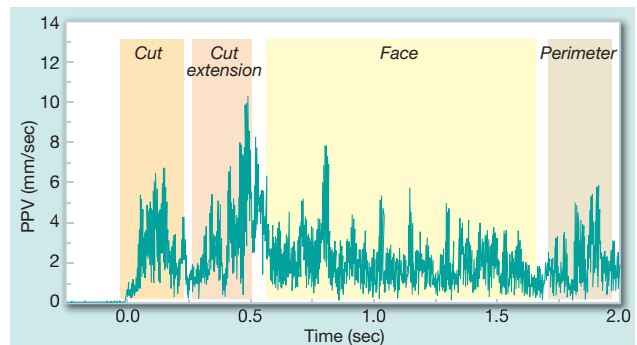
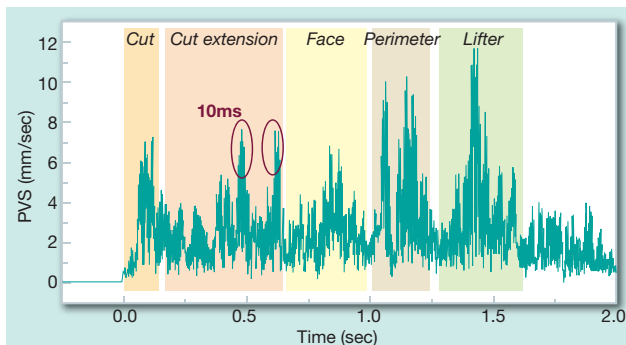


Table 1: Non-Electric vibration and airblast data

Initiation	Distance (m)	Result					Max. change wt/delay (kg)
		Vibration (PPV, mm/sec)				Airblast	
		V	T	L	PVS	dB(A)	
NE 1	290	1.11	2.13	2.68	2.94	105.5	6.375
	131	9.91	4.95	3.67	10.2	108.0	
NE 2	216	2.83	3.37	2.46	3.57	108.0	6.375
	296	0.714	0.826	0.603	1.10	97.4	
NE 3	206	5.75	2.95	1.86	6.54	107	25.5 (Off-set bunching not used)
	291	1.62	1.24	2.22	2.73	74.4	
	371	1.71	0.92	1.16	1.98	96.0	
	601	0.65	0.45	0.60	0.81	103	
NE 4	209	3.18	2.35	3.38	3.98	107	25.5 (Off-set bunching not used)
	294	1.51	1.44	1.59	2.00	104	
	374	1.73	1.05	1.29	2.06	94.8	
	604	0.35	0.35	0.52	0.57	101	

for the K (geological constant) and n (reduction level). This is expected in that all the results are taken in the same rock mass with similar explosive weight per delay and indicates that rock mass is not a significant factor for the difference in result.

It can however be seen that the regression line for the electronic blasts gives an r² value of 0.953 compared to 0.653 for the non-electric system. The r² value represents the Coefficient of Determination for the regression fit, being the degree of correlation between the estimated and actual y values. This indicates that the vibration prediction will be far more reliable with electronic blasting.

Comparing the vibration traces; the ppv generated in the cut was slightly higher for the electronic blasting system. This is not surprising as the design allowed for three shotholes firing same delay and the accuracy of the EBS would guarantee instantaneous firing of these holes. The non-electric system gave higher ppv in the cut extension, due to the fact of more shotholes firing within a tight

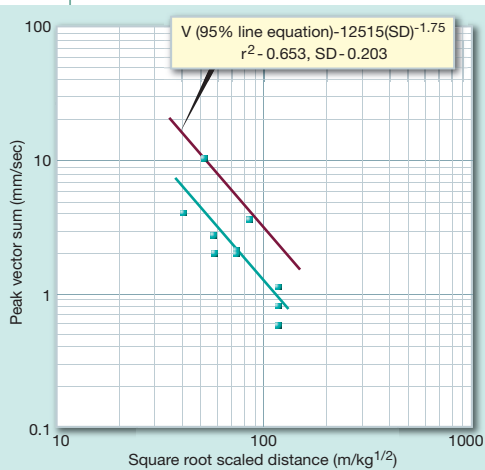
time window, and the EBS now operating on true single hole firing at 20ms interval. This is similar with the face where the EBS has true single hole firing and the NE system now operating with multiple holes firing at the upper end of the delay range. The EBS gave higher readings in the perimeter, probably due to multiple holes firing in batches on the same delay compared to the NE system. The highest vibration came from the EBS lifter area firing on 10ms delay. It is not fully understood why and more work is needed to assess if this is related to reinforcement due to a tight time window.

Fragmentation size analysis

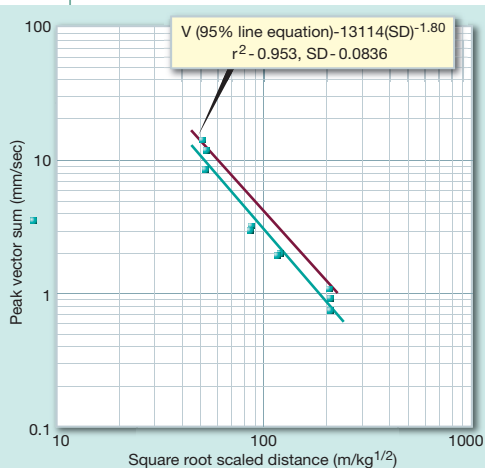
Fragmentation analysis was conducted for all five blasts using photographic image analysis. The non-electric detonator showed the average (P50) fragmentation size of 34.9cm versus 31.2cm for the EBS, indicating a size reduction of 11% with the overall results showing a uniform distribution. No direct conclusion can be drawn here.

Table 2: Electronic vibration and airblast data

Initiation	Distance (m)	Result					Max. change wt/delay (kg)
		Vibration (PPV, mm/sec)				Airblast	
		V	T	L	PVS	dB(A)	
EBS 1	294	1.70	0.619	1.17	1.92	98.2	6.375
	524	0.984	0.667	0.746	1.05	100.0	
EBS 2	134	11.2	5.02	5.21	11.7	98.0	6.375
	219	1.38	2.67	2.56	2.92	102.0	
	299	1.41	1.17	1.75	1.87	98.0	
	529	0.476	0.540	0.873	0.905	101.0	
EBS 3	137	8.26	2.16	2.92	8.37	97.2	6.375
	222	1.51	3.02	2.49	3.13	103.0	
	302	1.48	1.13	1.21	1.94	99.8	
	532	0.460	0.381	0.667	0.730	99.6	



Above: Fig 5 – Non-electric System Administrator



Above: Fig 6 – Electronic blasting system

Perimeter control

A series of images were taken of the perimeter at the completion of each blast for digital analysis, by assessment of Half Cast Factor (HCF) (figure 7). Owing to the change in rock type between left-hand and right-hand side, the results are presented as a series of comparisons between non-electric versus electronic, simultaneous versus delay, and the difference between simultaneous and delay in each side of the tunnel face.

The comparisons in figure 8 were obtained using the above analysis technique.

Table 4 (in figure 8) shows that all non-electric perimeters gave a HCF of 49.7% versus all electronic perimeters with 57.6%. This result is taken in both the left and right

Table 3: Fragmentation analysis results					
Passing size	NE		EBS		
	1st	2nd	1st	2nd	3rd
P ₂₀ (cm)	12.9	20.3	15.4	19.2	18.9
P ₅₀ (cm)	35.3	34.4	33.0	32.3	28.5
P ₈₀ (cm)	67.2	66.1	51.0	55.1	40.7
Top size (cm)	95.3	115.5	76.9	96.1	82.7

side of the tunnel face and with delayed and instantaneous firing.

Table 5 compares the EBS instantaneous firing with the EBS delayed firing of perimeter in both sides of the tunnel. Overall instantaneous firing gave a HCF of 68.85% versus delay firing of 44.75%.

Table 6 gives a comparison of instantaneous versus delayed firing in the right hand side of the tunnel where the RMR was 71 (classified as ‘excellent’ rock). Instantaneous firing gave 82.6% HCF versus 63.1% HCF with delay firing.

Table 7 shows the difference between instant and delay firing in the left hand side of the tunnel where the RMR was 41 (classified as ‘good’). Instantaneous firing gave 55.1% HCF versus delay firing with 26.4% HCF.

From these results it can be concluded that electronic blasting system firing has a positive influence on perimeter control compared to NE firing. It is also concluded that instantaneous firing of perimeter yields better result than delayed firing. The HCF analysis technique confirmed those observations made in the field where an obvious difference between system was noticed.

Tunnel advance

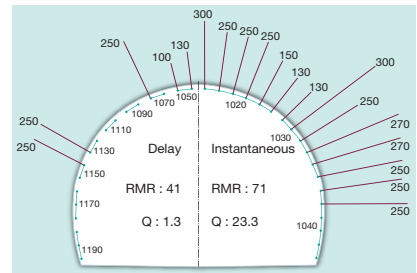
Measurements were taken of tunnel advance for each firing. Unfortunately, after some disappointing results due to a change in geology, for both the bench mark blasts and the first electronic blast, more shotholes were added to the round. No direct conclusions can be drawn here, other than the addition of more shotholes is significant to face advance (figure 9).

Conclusions

There are a couple of good pointers to where Electronic Blasting Systems (EBS) may offer value to the Tunneller. The firing and measurements were taken in a production environment. This meant no special controls were taken opposite drill accuracy and charging. It could be said that the positive results are most powerful in that the sole change was initiation timing and accuracy.

Most obvious was the improvement to perimeter control. Also the fact that vibration prediction proved to be more reliable will have value to tunnellers. Often cautious limits are set for maximum charge weight to overcome variability in vibration results. Charge weight limitation usually results in shorter drill length and therefore reduced advance per cut. Being able to maximise advance for a given set of criteria is of enormous value.

The electronic timing designs were not optimised for vibration control. Opportunities exist to further refine these designs to give true single hole firing to minimise charge weight per delay.



Above: Fig 7 – HCF (Half Cast Factor)

Table 4: HCF of all Non-Electric Perimeters versus all Electronic Perimeters

H.C.F	0-25	25-50	50-75	75-100
V.P		P	G	V.G.
NE	[Bar chart showing NE HCF distribution]			
EBS	[Bar chart showing EBS HCF distribution]			

Table 5: HCF of EBS Instantaneous Batch versus Delay Fired Perimeters

H.C.F	0-25	25-50	50-75	75-100
V.P		P	G	V.G.
EBS Instantaneous	[Bar chart showing EBS Instantaneous HCF distribution]			
EBS Delay	[Bar chart showing EBS Delay HCF distribution]			

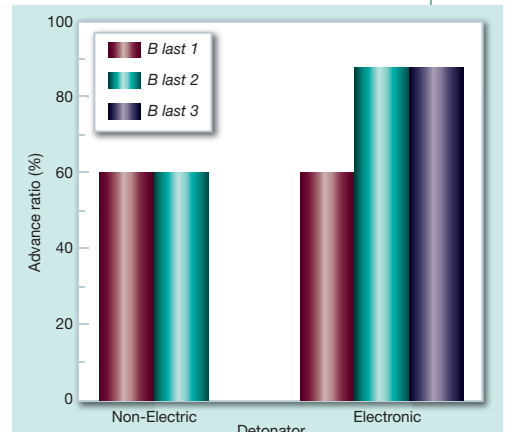
Table 6: Instantaneous Firing versus Delay Firing in Excellent Ground (RMR-71)

H.C.F	0-25	25-50	50-75	75-100
V.P		P	G	V.G.
EBS Instantaneous	[Bar chart showing EBS Instantaneous HCF distribution]			
EBS Delay	[Bar chart showing EBS Delay HCF distribution]			

Table 7: Instantaneous Firing versus Delay Firing in Good Ground (RMR-46)

H.C.F	0-25	25-50	50-75	75-100
V.P		P	G	V.G.
EBS Instantaneous	[Bar chart showing EBS Instantaneous HCF distribution]			
EBS Delay	[Bar chart showing EBS Delay HCF distribution]			

Above: Fig 8 - Tables 4, 5, 6, and 7



Above: Fig 9 – Advance ratio comparison

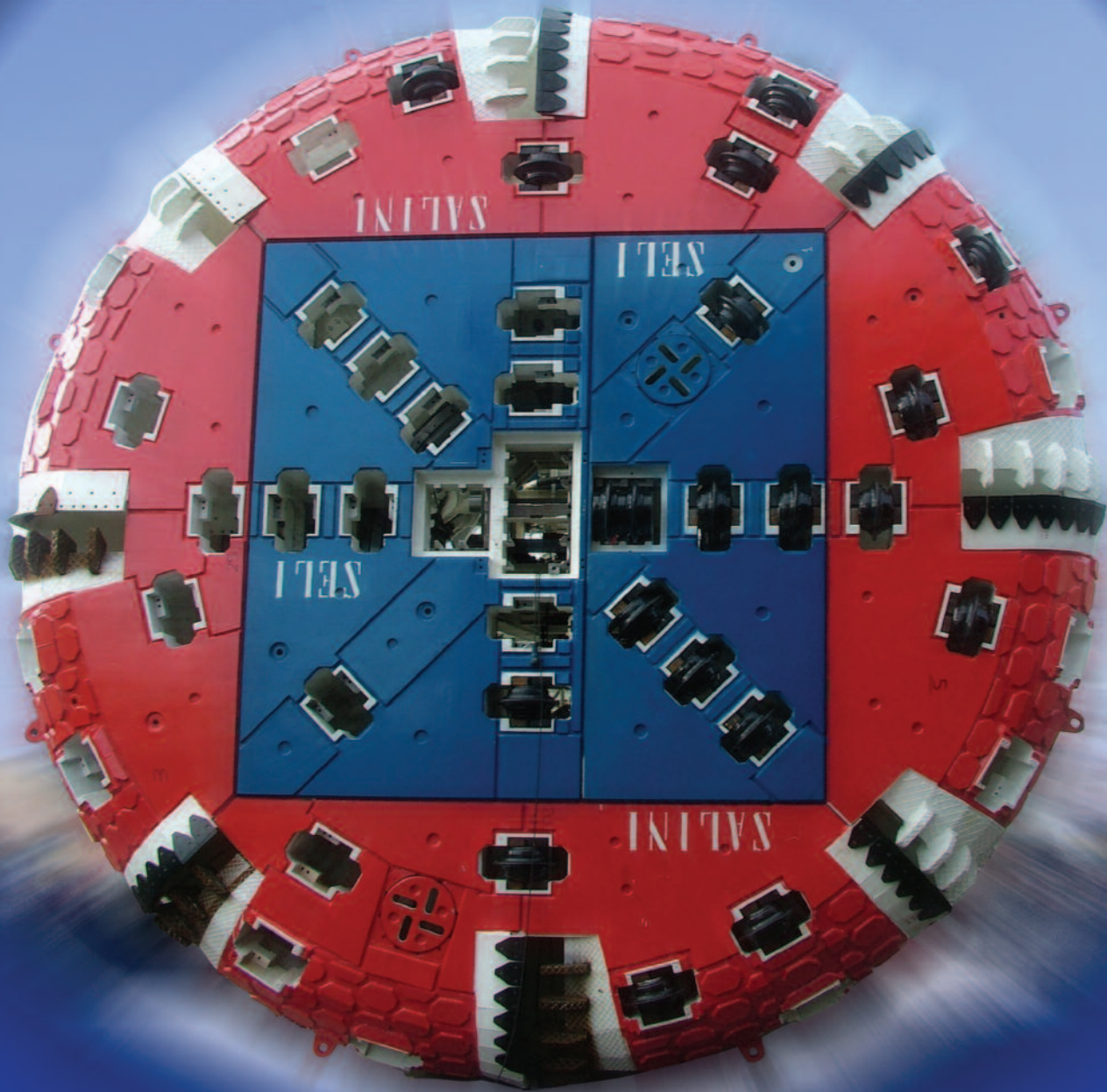
ACKNOWLEDGMENTS

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The Hanwha Blasting Engineering Team for their dedication and support in conducting ‘round the clock’ measurements at critical stages of the tunnelling cycle.

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Looking at tunnel roughness

Research at Kárahnjúkar, Iceland, is providing fresh insight into tunnel wall roughness to estimate headloss. Report by Patrick Reynolds



Above: Visual inspection of tunnel wall roughness in Kárahnjúkar headrace during construction to investigate frictional headlosses

Below: Fig 1 & 2 - Rock class - Smooth



Below: Fig 3 & 4 - Rock class - Medium



Below: Fig 5 & 6 - Rock class - Rough



The TBM drives for the headrace tunnel of the 690MW Kárahnjúkar hydropower scheme, in Iceland, found highly varied geological conditions, particularly with the large water inflows that were suffered in some parts of the bores. Beyond that tough construction experience, however, different lessons are being learned that should be useful for tunnel lining works in a wider range of water projects thanks to client-sponsored research into surface, and hydraulic, roughness.

The client, national power company Landsvirkjun, was naturally focused on headloss in the hydraulic system not only for fundamental economic reasons but also due to the potential scale of lost energy, given that the 7.2m-7.6m diameter headrace

tunnel is 39.6km long. Prior to the research, design estimates used in planning the project estimated the hydraulic friction losses at anywhere between approximately 60m-95m, which is about 10%-17% of the nominal gross head.

Beyond the immediate client, other project sponsors with water tunnels in which headloss is of key importance can also draw upon the research to help secure additional economic and operational benefits. They will require the supply side services of designers and contractors to absorb the research findings to help estimate, monitor and adjust the surface roughness of tunnel lining works during the construction phase.

Research project

The Kárahnjúkar hydropower project marked the first use of TBM tunnelling in Iceland.

Design and construction of the scheme has been a significant international effort, drawing upon services from local and foreign consultants in the client's design engineer Kárahnjúkar Engineering JV (KEJV) – VST Consulting Engineers, Pöyry, MWH, Raftækning and Almenna Consulting Engineers. The design programme commenced in 2000. As local practice prevents the designer from supervisory duties, a consortium was hired as owner's representative – VIJV, which comprises Mott MacDonald, Linuhonnun, Hnit, Fjarhitun, Sweco, Norconsult and Coyne et Bellier.

The main contractor undertaking the KAR-14 headrace and Jokulsa diversion tunnel works under a re-measurement contract, and other works, is Impregilo. The headrace and diversion tunnel have been excavated through varied volcanic and sedimentary rocks mostly by TBM with some drill and blast, though slightly more than initially planned. Three TBMs – two 7.2m diameter main beam shields and a 7.6m diameter machine – were supplied by Robbins for the project (T&T, January 2007, p4). Excavation of the headrace commenced in mid-2004 and finished late 2006, and the Jokulsa branch is almost completed.

The view was that the available technical data on roughness of long water tunnels was incomplete and of limited reliability. In particular, there was a lack of information on



Above: Tunnel wall roughness research in the dominant, TBM-bored parts of Kárahnjúkar headrace was done by establishing surface categories through visual inspections, and some laser scan measurements were undertaken

Below: The laser scanned vertically-separated strips of wall surface



unlined TBM-driven tunnels due to limited data from the construction phase. The idea for the tunnel roughness measurement programme came from lead headrace tunnel design engineer, Joe Kaelin, of Pöryr Energy. He also supervised the studies, undertaken by others in KEJV - local firm VST in conjunction with Pöryr - and completed during the headrace excavation. The research effort was supported by VIJV and Impregilo.

A different, established approach - Rønn's "IBA" method, from Norway - was used to assess headloss in unlined tunnels excavated by drill and blast. The method is one of many approaches and is based on measurements of cross section and longitudinal geometry over 20m-25m long portions of tunnel to calculate wall roughness and equivalent hydraulic friction.

To prepare for the studies on the TBM drives, the team drew upon methodology of wall roughness and hydraulic headloss studies established by Pegram and Pennington, in the report to the Water Research Commission by the University of Natal. It included the case study of Delivery Tunnel South of the Lesotho Highlands Water Project (LHWP), but looked at different surface types (sandstone, granite, shotcrete and concrete) in TBM-driven tunnels in general. Laser measurement was used in four tunnels, two in LHWP.

Measurements – visual inspection

At Kárahnjúkar, the aim was to collect physical measurement data during construction along the entire length of the headrace. Limited time and budget, however, kept the visual inspections to 50m intervals over 2005-6.

A 1m wide strip of rock was inspected below springline, at springline level and in the crown at the side of the tunnel, opposite the mucking out conveyor, to categorise intact rock or shotcrete into different roughness classes – smooth, medium and rough. The classes were defined to represent the range of observations and were based on measurements of the maximum average deviation of the wall surface from a straight bar ruler - 40cm long for rock surfaces, 80cm long for shotcreted surfaces; they are, in principle, independent of geology.

It should be noted, though, the observations took into account planned finishing work subsequent to inspections.

Observed large-scale rock features, such as joints and/or pockets, were classified into four categories by the depth and number. In total, almost 90% of the TBM drives were inspected visually.

In summary, a quarter of the inspected tunnel was shotcrete lined, and those sections classed as: smooth (14%); medium (64%); and, rough (22%). While rebound shotcrete prevented some 4% of the unlined rock surfaces from being classified, those assessed were classed as: smooth (26%); medium (65%); and, rough (9%).

In terms of the geological strata, those rocks with proportionally more rough surfaces ranged from pillow lava, tillite, and cube jointed basalt in decreasing order to andesite, scoria, pillow breccia, scoracious basalt, conglomerate, olivine basalt, porphyric basalt, tholeiitic basalt, and sandstone/conglomerate, and sandstone.

Finally, at the other end of the range, siltstone and sandstone/tuff were classed as having with no rough surfaces.

Observations of the range of joints and large scale irregularities concluded that about 45% were sparse and/or shallow, a quarter were dense and/or deep, a quarter were free of joints, and approximately 5% of the surfaces contain large rock break-out.

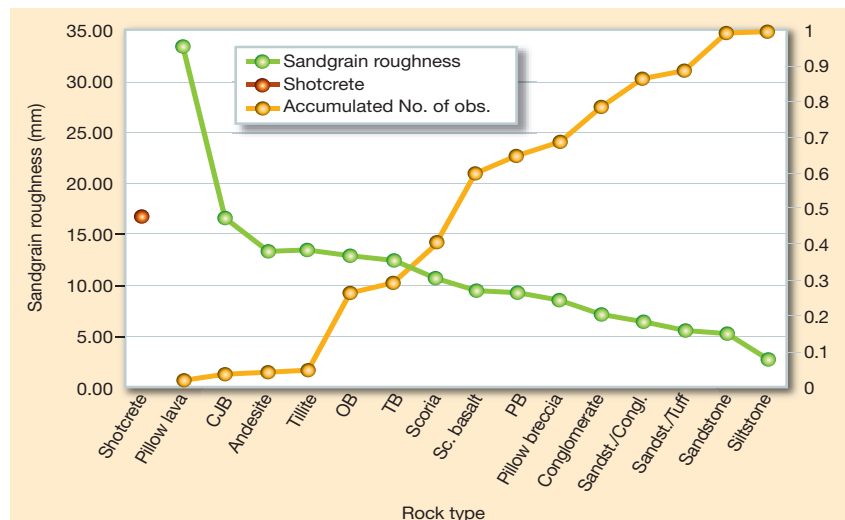
Rock with many and/or deep joints were found, in decreasing order of importance, associated with: cube jointed basalt, pillow lava, tholeiitic basalt, olivine basalt, tillite, andesite, porphyric basalt, scoria, pillow breccia, scoracious basalt, sandstone/tuff, conglomerate, sandstone/conglomerate, sandstone and siltstone. Joint-free surfaces were found in association with: siltstone, sandstone/conglomerate, sandstone, conglomerate, sandstone/tuff, scoracious basalt, scoria, tillite, porphyric basalt, cube jointed basalt, olivine basalt, tholeiitic basalt, pillow lava and andesite.

Measurements – laser scan

Laser scans were executed at approximately 10% of the visually inspected surfaces. Rock surfaces were measured - using a FARO Scan Arm portable coordinate measuring machine - below springline level, and shotcreted surfaces above springline level as the upper parts were lined when measurements were taken.

About 600 profiles were scanned at 73 different locations over nine months. The sites to be scanned were chosen from photographs to represent the different roughness classes, and were dry, or had to be dried, before the scan. The support platform for the scanner was bolted to the wall and the head of the scanner fixed to a 1m long bar. Steady motion scanning was facilitated by a manually-operated cogwheel.

Scans were made of the walls in



Above: Equivalent sand grain roughness calculated against rock type



Above: Following the visual inspection to pre-categorise the rocks into roughness classes, about 10% of inspection sites were scanned by wall-mounted laser

40mm–60mm wide strips, each strip comprising 640 points. The coordinates are scanned with an accuracy of 0.1mm and point spacing of less than 0.25mm. At each survey site, the scanner measured two 40mm wide by 1m long strips, separated vertically by about 100mm. Four profiles with a vertical separation of 8mm were extracted from each scanned strip, which provided eight roughness profiles scan sites. The average sample spacing was 0.1mm.

Data analysis

The data obtained from the visual and laser scan measurements were processed according to the method developed by Pegram and Pennington, which transformed the data from physical to hydraulic

roughness. These drew upon three parameters: equivalent sand grain roughness; a friction factor; and, a flow resistance coefficient.

Wall roughness in TBM-bored tunnels has a wave-like structure that varies with geological strata as well as the operation of the cutterhead, though data on TBM advance rates were not explicitly compared to intact roughness. The researchers note further that the scale of the roughness arising from cutting speed or method is usually an order of magnitude smaller than that due to geology. The wave properties can be calculated from laser measurements.

In the initial design estimates, the equivalent sand grain roughness for unlined TBM drives was taken as 10mm, and 20mm

for shotcrete walls. The data indicated that 40% of the headrace had a larger roughness value and 60% lower. The average value for the shotcrete walls was determined to be lower than estimated, at 17mm.

Based on the calculated roughness data, and taking the 7.6m diameter TBM to have bored 14.7km and the two 7.2m diameter machines to have excavated a total of 20.8km, the specific headloss in per unit length of the tunnel was determined. The researchers note that the calculations showed specific headlosses for shotcrete sections to be similar to those for rock with large break-out, partly due to the minor throttling effect of its thickness slightly reducing the internal diameter of the tunnel.

Based on the measurements and data analyses, the research determined that the overall headloss from friction in the TBM-bored section of the headrace was 64m with a tolerance of 10%, which puts it at the lower end of the initial design estimate.

Verification work is now underway to derive the headloss in the headrace during operation of the power plant, which started-up last year. While the headrace is not yet carrying the full, design flow rate, so far the direct measurements show that operational headloss is 6% less than that predicted from the roughness measurements.

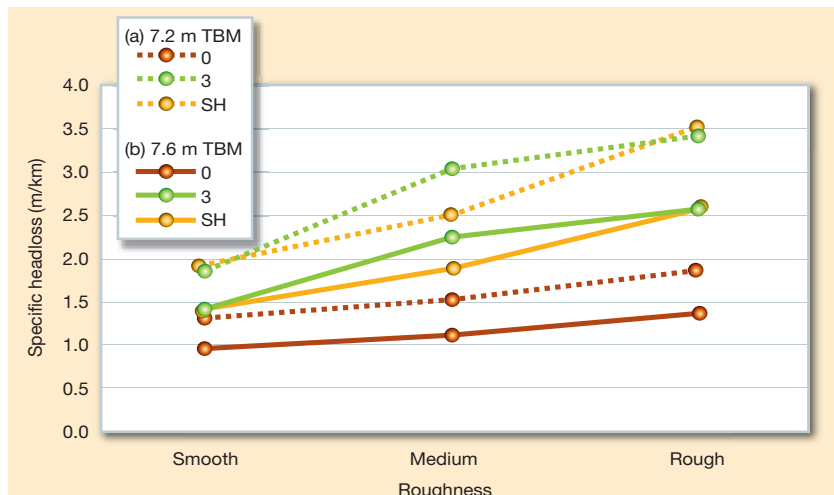
R&D and applicability

The researchers say the key area for further research is to improve the accuracy of matching the scanned data of wall roughness to the equivalent sand grain roughness, independent of tunnel diameter.

Their hope is to gain backing to undertake laboratory tests to refine the knowledge of how equivalent sand grain roughness relates to actual wall surfaces. Such research will benefit all water conveyance tunnels.

The findings can also assist in managing changes to lining works that might be required or arguably be of longer-term benefit to a client. There is always the possibility of following up the construction phase to ensure the contracted performance has been delivered.

T&T



Above: Specific head loss ranges in different diameter section of headrace

ACKNOWLEDGEMENTS

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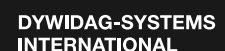
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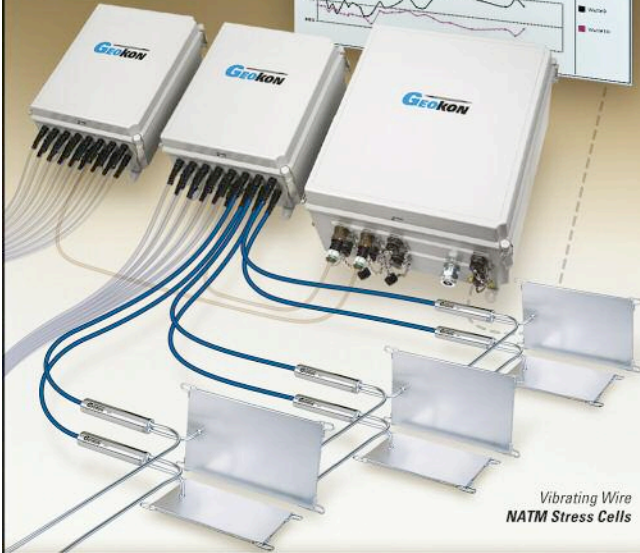
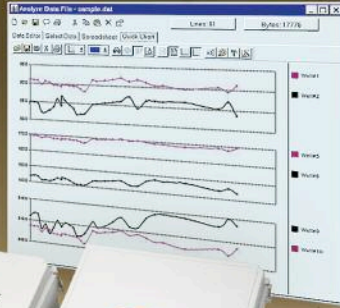


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Global Claims

Before looking at global claims it is worth reminding ourselves of some basic common law principles as to what is meant by the recovery of damages and how they should be assessed. These are enumerated as follows:

The aim of damages for breach of contract is to put the claimant back in the position he would have been had the contract been performed as was intended^[1].

When pursuing any claim the claimant has to prove:

- That the breach of contract or duty or other claims' event has actually occurred
- That the Respondent is factually and legally responsible for it and
- The loss claimed was caused by it

In complex cases there may be some difficulty in assessing what the damages are to flow from the offending party's breaches of contract, where it is clear that some loss has been suffered then a court

or arbitral tribunal is bound to do the best it can based upon the evidence available^[2].

What is a Global Claim?

Difficulties arise then when a claimant makes a global claim, or as they are known in the US a total cost claim. In such an approach the claimant in effect says there a number of reasons, or heads, under which I make my claim, arising out of all of those heads I have incurred losses, it is not however possible or practical to assess which part of the money belongs to which head of claim.

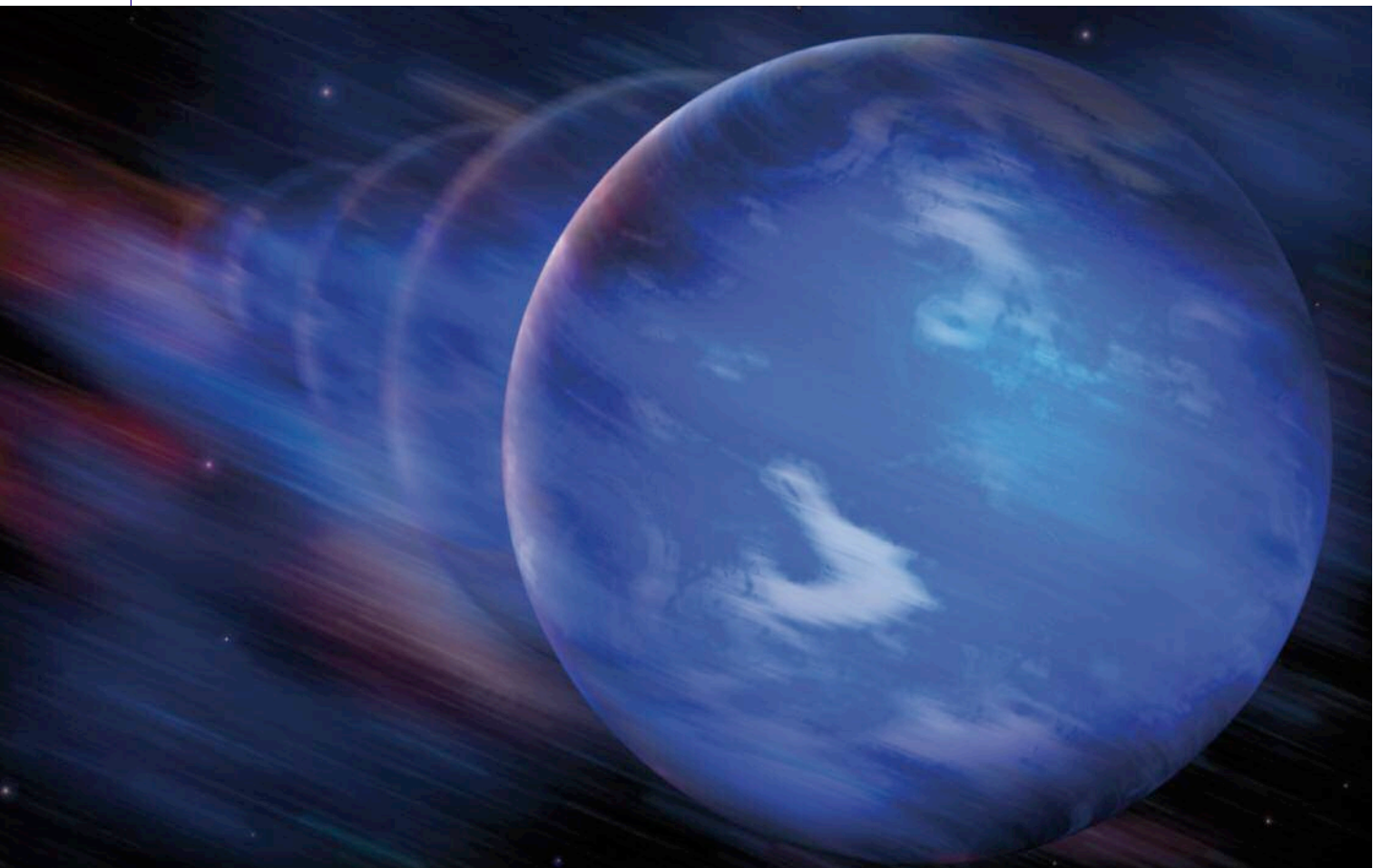
The danger which has been perceived over the years to this approach is that the lack of particularity in the claim may mask losses that have been included by the claimant, which are either in fact the legal liability of the claimant themselves or are 'neutral' events.

Such neutral events might be weather-related delays where the claimant is entitled to additional time but not

A standard defence to any claim submitted by a contractor is, "it is a global claim and so it should fail completely". *T&T*'s contracts and disputes correspondent, Paul Cullinan of Plus 3 Consultants, examines what is meant by the phrase global claim and some common law developments which could show that the tide is receding from the high water mark where a defendant's assertion that a claim was global was sufficient to send a contractor packing

necessarily the money that goes with it.

It has been argued that to defeat such a global approach it is simply necessary to defeat one of the grounds for all the others to then fall, put the other way, for the claimant to succeed in a claim with



ten heads of claim relating to one lump of money, then he has to hit the buttons on all ten heads to claim any of the money. It is submitted that by following the line of common law cases on this subject and the recent Scottish case of John Doyle -v- Laing Management in particular, that such a view would not be safe.

Line of Common Law Cases

As noted then, the problem of so called global claims have been considered over a series of cases in the context of construction contracts, firstly in the case of *J Crosby & Sons Ltd v Portland Urban District Council*^[3] where Donaldson J said: "I can see no reason why the arbitrator should not recognise the realities of the situation and make individual awards in respect of those parts of individual items of the claim which can be dealt with in isolation and a supplementary award in respect of the remainder of these claims as a composite whole."

In the case of *London Borough of Merton v Stanley Hugh Leach*^[4] Nourse J said: "If application is made ... for reimbursement of direct loss and expense attributable to more than one head of claim and at a time when the loss and expense comes to be ascertained, it is impractical to disentangle or disintegrate the part directly attributable to each head of claim then, provided of course that the contractor has not unreasonably delayed in making the claim and so has himself created the difficulty, the architect must ascertain the global loss attributable to the two causes..."

The thrust of these cases then is that, where a tribunal is able, it should make awards on the identifiable heads, there may then be a residual amount where that is not possible and the approach then to be taken is one of making a supplementary award for those parts of the claim which are indivisible.

The approach in these two English cases was departed from somewhat in the Hong Kong case of *Wharf Properties v Eric Cumine Associates (No 2)*^[5] where an Employer's claims against its architects for negligent design and contract administration were struck out as incomplete and therefore disclosing no reasonable cause of action. It should be noted that Wharf was a judgment of the Privy Council, that is, it is the same judges who sit in the House of Lords only

"THE CLAIM IN WHARF WAS STRUCK OUT ONLY BECAUSE THE CASE, AS PLEADED, WAS AS THEIR LORDSHIPS PUT IT, HOPELESSLY EMBARRASSING"

"IT SHOULD BE A SIMPLE ENOUGH TASK FOR EXAMPLE TO DETERMINE WHAT PERIODS OF TIME WERE TAKEN UP IN THE MORE PROBLEMATIC SECTIONS OF A TUNNEL DRIVE"

wearing a different 'hat', so to speak, when they hear cases from outside the English jurisdiction, in this case Hong Kong. It is probably the weight attached to being a Privy Council judgment that has led to this case leaving a lasting impression that global claims should be struck out.

That said, whilst the Wharf approach does appear to conflict with the Crosby principle it should be noted that the claim in Wharf was struck out only because the case, as pleaded, was as their Lordships put it, 'hopelessly embarrassing'. Further, the judgment is at pains to point out that:

"As the argument has progressed, ... it has become apparent that the case, whilst of obvious importance to the parties because of the sums involved, raises no question of any general importance, so that, in the event, their Lordships' Board has been, exceptionally, concerned with a pure point of pleading peculiar to the particular dispute in which the parties are engaged."^[6]

An English case where the court must have felt that the pleading was not so 'hopelessly embarrassing' was that of *Bernhards Rugby Landscapes Ltd v Stockley Park Consortium Ltd*^[7] where HH Judge Humphrey Lloyd gave the plaintiff leave to amend the claim since:

"its current form is not so oppressive or abusive as to justify refusal of leave to amend The deficiencies may ... be cured by the provision of particulars or in some other way."

The Controversial John Doyle Case

As noted above, the most recent case to cause a stir in this controversial areas of the law is that of *John Doyle Construction Ltd v Laing Management (Scotland) Ltd*^[8], this is a case from the Inner House of the Court of Session in Scotland (that is the Scottish Court of Appeal).

The case involved the construction of a new corporate headquarters for Scottish Widows. Laing argued that Doyle had made a global claim (US\$9.6M) and if any of the loss and expense in it was not caused by them the claim must fail. However, the Court held that:

That so long as the claimant can prove

that all the events arise from defendant-culpable reasons and that they do not include any claimant-culpable or neutral events; that loss and expense has been suffered by the claimant and that there was a causal link between the two, then there is no need to demonstrate that particular heads of loss are attributable to individual events.

If a defendant asserts that there were claimant-culpable concurrent causes of delay which defeat the global claim then it is sufficient for the claimant to show that the defendant-culpable events were the 'dominant cause' of either the delay and/or the loss.

Even where it is evident that the defendant-culpable events are not the dominant cause of delay and/or loss then it may be possible to undertake an apportionment between defendant-culpable causes and other (that is claimant-culpable and neutral causes), the Court recognised that this might be a rough and ready process.

Global Claimant's Charter?

It can be seen that in this case claimants have been given considerable benefit of the doubt and 'get-out-of-gaol' cards to get home on their global approach. The decision has attracted equal amounts of praise and criticism depending on whether one represent contractor or employer 'camps', some commentators even going so far as to say the case may be what happens north of the border but it does not represent English law^[9].

Unfortunately for them Doyle has received some measure of approval in the English courts in the recent case of *London Underground Ltd -v- Citylink Communications Ltd*^[10]

It is submitted however, that far from being a global claimant's charter Doyle can be seen as simply as a restatement of some of the principles enumerated at the outset, that is that in cases where there are difficulties of assessment then the court or tribunal must simply do the best it is able based on the evidence.

There is sufficient caution within the line of cases cited, including within Doyle itself, to highlight to any claimant that embarking on a strategy of a global claim does still carry considerable risk.

Surely it is better for any claimant to spend a little time, effort, and yes, money to establish as best they can which

tranches of money claimed belong to which delay or other event they are complaining of. Rather than, throw themselves on the mercy of the court or tribunal to come up with some apportionment which may well be a fraction of the claimed amount.

Attributions where possible

In most instances with a modicum of diligence it will be possible to establish various sources of cost, for example whilst general project management costs may not be, on-site supervision should normally be attributable to certain sections of the works.

Likewise, it should be a simple enough task for example to determine what periods of time were taken up in the more problematic sections of a tunnel drive, assuming the contract makes these Employer risk events, then one has a starting point for identifying the time related costs attributable to that period when the problems occurred.

On occasions there are genuine difficulties in gathering together sufficient particulars to make a realistic attribution

of losses arising from particular events, however on other occasions, it has to be said it is simply a case of laziness and bad practice on the part of the claiming party.

The approach should be to make a court or tribunals task as straight forward as possible and protect ones own position by ensuring that as much of the claimed amount as possible is divided into attributable portions.

Reliance on global claim defence

For defending parties too there is quite some considerable risk in playing the global claim card, it is rare in any dispute resolution process that one will be gifted the knock-out blow of having one's opponents case struck out completely.

Whilst it is not unusual to see the global claim defence pleaded only in the first alternative it should not be relied on to the extent that a defending party does not concentrate on defeating the claimant's assertions on their individual merits, nor rolling up one's sleeves and getting into the detail of the figure-work submitted by the claimant in support.

Conclusion

In conclusion therefore, some comfort can be taken by contractor claimants that the judicial tide is with them in terms of a reluctance to strike out claims at the first cry of 'global claim', however the approach should still be used with great caution, lest one's claim be labelled as 'hopelessly embarrassing'!

T&T

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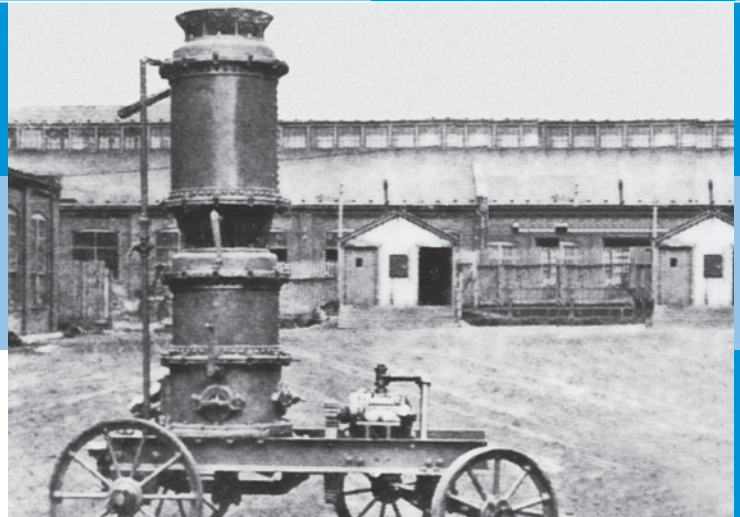
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Obituary

Denis Mahoney (1947 - 2007)

A well known and much liked British Tunnelling Society member, Denis Mahoney, died suddenly from a heart attack on 16 December, aged 60, following a full and wide-ranging career in many areas of tunnelling and civil engineering construction.

He gained his BSc Degree in 1971 at the end of six years with consulting engineers Nachshen Crofts and Leggatt. He then joined Mott Macdonald and was involved in the design of building infrastructure, sea defences, roads and became a Section Engineer on the 2nd Dartford Tunnel.

From there he moved to civil engineering contractor, John Mowlem, where he worked for twelve years on a range of dock and harbour works, roads, sewers, rail works and tunnels rising to site agent for the Kessingland Bypass (Norfolk) and assisting with numerous tenders for dock works and tunnels. The tunnels included cooling water outfall tunnels at Redcar and compressed air working in tunnels in London's docklands.

Joining Pemberwell Services Ltd in 1988 he was first seconded to Channel Tunnel where he undertook a review of safety measures and training. Contemporaneously he assisted groundworks contractor Sugrue Ltd with responsibility for method design and safety of excavations and temporary works in city areas.

From there he was seconded to the London Underground Jubilee Line construction team for the duration of the project. Here he initially provided support to London Underground for the project Parliamentary Report. He then went on to lead the programme management for the west section and gained responsibility for delivery of Southwark Station, crucial to the opening of Phase 1.

Denis's diligent research into historical archives at the ICE uncovered serious difficulties and obstructions encountered during construction of the City and South London tube (now the Northern Line) at London Bridge, which led to important changes to the layout of the Jubilee Line at this complex interchange.

In 1998 with the retirement of the owners of Pemberwell he, and the then company secretary, took over the running of the consultancy and staff procurement business. He continued his project work for various clients particularly

London Underground. In 2002 he was seconded full time to London Underground Engineering Directorate where he participated in a range of activities leading to his appointment in 2005 as Project Assurance Engineer for three major projects viz. White City Development, the East London Line Extension and Stratford Station Development.

A senior colleague of Denis's in LU writes: "Each of these projects has a number of powerful stakeholders and are valued in hundreds of millions of pounds. This seemed to be just the sort of challenge Denis excelled in. His diary was generally crowded but he had that special knack of identifying priorities whilst finding the time to assist those colleagues that called for help".

There were three parts to the White City Project: The new stabling for Central Line Trains under the new shopping centre; the works at Shepherds Bush station; and the new station at Wood Lane. Denis played a pivotal role in meeting the delivery dates for bringing the new stabling sidings into use. The works at Shepherds Bush are in construction where the below ground tunnelling works were of particular interest to Denis because of their technical complexity. The new elevated station at Wood Lane on the Hammersmith & City Line is in the early stages of construction.

The East London Line owes a lot to Denis's diligent attention to detail and interpretation of assurance requirements between Network Rail and London Underground standards. This was against a background of changing stakeholders as the project moved from Strategic Rail Authority through Network Rail to Transport for London sponsorship and from London Underground being the operator to this role being given to the concessionaire London Overground Rail Operations Ltd.

Additionally the law changed in 2006 from ROTS to ROGS requiring London Underground to be self-assuring. Denis took on the task of turning theory into practice and in educating his colleagues on what they needed to do differently to stay within the law. His favourite method of resolving a difference of opinion was to ask, "what would the man in the curly wig say?".

Stratford station redevelopment was equally demanding but at an

earlier stage in the planning.

There is no doubt that Denis made a valuable contribution to the confidence with which London Underground can deliver its major projects.

Denis remained a co-director and owner of Pemberwell during his secondment to London Underground continuing to provide advisory services and experienced staff secondment to clients.

Outside his busy working life Denis was an active member of

his church in Rayleigh. He played an important role in local youth activities, played squash on a regular basis and enjoyed holidays with his wife and family in far-flung parts of the world, which often involved some voluntary work.

Denis was a well respected, and likeable man, and will be sorely missed by his many friends and colleagues in the industry. We send our sincere condolences to his wife, Sue, and their family.

Dr Ralph B Peck (1912-2008)

A leading authority in the science of geotechnical engineering died on 18 February 2008. Dr. Ralph Peck passed away at his home in Albuquerque, New Mexico, aged 96.

Peck is recognised as the successor and pioneer of the work started and developed in the fields of soil mechanics and geomechanical engineering by his mentors Karl Terzaghi and Arthur Casagrande.

With a degree (1934) and a PhD (1937) in Civil Engineering from Rensselaer Polytechnic Institute in Troy, New York, Peck attended the soil mechanics course at Harvard University and was a laboratory assistant to Casagrande (1938-39). He then represented Terzaghi as an assistant subway engineer on the Chicago Subway Project for the City of Chicago from 1939-42.

In 1942 he joined the University of Illinois and was a Professor of Foundation Engineering from 1948-74.

In 1948, Terzaghi and Peck co-authored perhaps the most influential textbook in geotechnical engineering, 'Soil Mechanics in Engineering Practice'. In 1953 he co-authored with Walt Hanson and Tom Thornburn the benchmark textbook 'Foundation Engineering'.

On retiring as Professor Emeritus at the University of Illinois in 1974 and moving to Albuquerque, Peck continued an active consulting practice that included more than 1,000 consulting projects across the United States and in 28 countries of the world. Among these were the rapid transit systems in



Chicago, San Francisco, and Washington DC; the Alaskan Pipeline System; the James Bay Project in Quebec; and the Dead Sea dikes.

Peck served as President of the International Society of Soil Mechanics and Foundation Engineering from 1969-73. In 1974, he was awarded the National Medal of Science by President Ford. Other honours include the Norman Medal, The Wellington Prize, and the Outstanding Lifetime Achievement Award in Education from the American Society of Engineers. His last project was the Rion-Antirion Bridge in Greece, which received the ASCE's OPAL Outstanding Civil Engineering Award for 2005, the only project outside the United States to be so honoured.

Professor Peck is missed by a son and daughter and their families and memorial contributions were requested to the Ralph B Peck Geotechnical Engineering Fund University of Illinois Foundation, 1305 West Green Street, MC-386 Urbana, Illinois 61801, USA.

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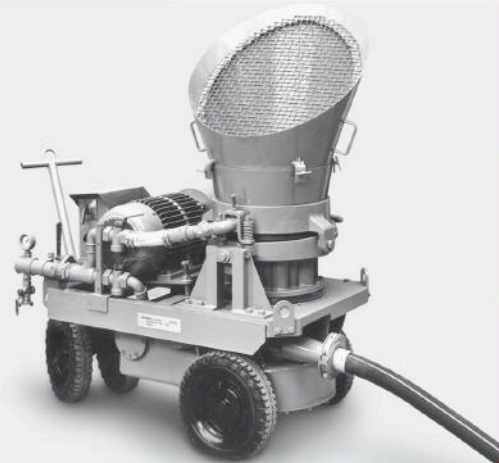
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Products

Shuttle service



Efficient concrete transport in tunnelling is crucial. Rowa Tunnelling Logistics has developed the RoConShuttle concrete transport system with just this in mind. Rowa has focused on improving the performance of the drum mixers to provide a higher filling rate for the transport cars, continuous concrete agitation during transport, reliable conveying of concrete to the pump, possible addition of additives or neutralisation in case of accidents, reduction of residual concrete resulting from complete emptying of cars, and faster cleaning and easier maintenance via better accessibility. The track-bound RoCon Shuttle benefits

from a modular design and transports concrete through up to three 11.25m³ capacity shuttle cars with open trough mixers to the concrete pump. The troughs consist of self-supporting sheet-plate structures supported on a car chassis. The troughs are open at the top, covered with a removable grid incl. vibrator. A hydraulically operated slide valve is fitted at the in- and outlets of the trough. A hydraulic agitator is integrated in the trough.

The agitator features a central shaft with welded on helical sections that can easily be replaced when worn. Hydraulically driven, it is used for agitation and forward movement of concrete. The conveying system consists of a steel cone with vulcanised-on seal and a steel funnel as a coupling element.

The positioning mechanism has a hydraulic tension device at the coupling to pull the cars together during emptying. The shuttles are transported by the two-axle RoCon Powerpack car via the RoCon Pumpstation car.

Fan supplies to UK

Elta Fans, the global manufacturer and supplier of fans and air movement products, has been appointed to design and supply fans for two major tunnel developments.

Contractor Balfour Beatty, working for the Highways Agency, has already taken delivery of its temporary ventilation for the Hindhead bypass, which will provide a dual carriageway link from London to Portsmouth. The 1.4m diameter contra rotating fans were designed and manufactured to extract machinery fumes and dust to provide fresh air whilst the tunnel is under construction.

The units have been constructed utilising heavy attenuators and by housing the fans inside acoustically lagged containers, noise pollution has been kept to a minimum.

Work is also due to commence

With this new system Rowa promises improved cost efficiency, simple and quick filling of the concrete transport cars, constant optimal concrete quality, and

later this year at Elta on a US\$300,000 contract to supply ventilation for three underground tunnels housing high voltage electric cables in East London. The EDF Energy and National Grid tunnels require specialist ventilation to remove the heat produced by the electric cables along with being required for smoke clearance in the event of a fire. Elta Fans' smoke ventilation ranges is specifically developed for general ventilation plus emergency smoke extract and the company has recently extended its EC-Certification for smoke related fan units with BSI, making it one of the largest certified standard product ranges available within Europe.

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Products

50 years of innovation

Meyco Equipment, a division of BASF Construction Chemicals, has showcased its latest developments including the Meyco Potenza or Meyco Roadrunner equipped with the Meyco Maxima spraying manipulator, a spraying arm of a new generation with ground breaking features. The Meyco Maxima, claims Meyco, will help customers complete their tunnelling, faster, more efficiently, and safer.

In 1957 the company invented the Meyco GM 57, a dry-spraying machine using rotor principles, allowing continuous spraying. Since then the company has consistently updated its products. In the early nineties Meyco developed the then Meyco Suprema, which became, with its PLC, computer control, push-over system and Meyco Dosa



TDC dosing technology, the first specialised wet-spraying machine. The Meyco Logica which followed, can scan working areas and spray to preprogrammed parameters in semi or full automatic mode.

But not just the machines are unique, the philosophy of providing a complete range of relevant chemical products together with the appropriate equipment and service was a vision provided jointly by Meyco and UGC International (both divisions of BASF Construction Chemicals).

Parallel to the technological "breakthroughs" Meyco has consistently produced special solutions for customers with specific requirements such as on TBM back-ups and shaft platforms.

But Meyco has not forgotten its origins and still manufactures the rotor machines that started the half-century of innovation and dedication to perfecting the art of spraying concrete.

Meyco Equipment
Tel: +41 58 958 2732
Web: www.meyco.basf.com

Clear visibility via OBM

With major tunnelling projects it is as important to monitor rock faces for signs of possible geological deformation as it is to continuously verify the tunnel's alignment and dimensions.

On the 12.3km Vienna Lainzer rail tunnel project, for the Austrian railway company OeBB, Consulting Messtechnik (Comet) is employing a motorised high precision surveying instrument to monitor excavation work.

This system is called OBM and was developed and engineered by Comet and unlike most other alternatives, which use prism targets to obtain readings, it employs electromagnetic reflectorless distance measuring technology. It is designed to operate 24/7 without maintenance, taking readings from around 20 different points in 12 minute cycles to an accuracy of +/- 1mm.

To ensure maximum efficiency and accuracy, Comet has introduced a novel way of keeping its equipments lenses clean – an Air Control Industries blower



supplied by the company's German distributor Carl von Gehlen. Whilst other systems require surveyors to clean lenses manually at frequent intervals, the Comet system's lenses are kept dust free at all times by the blower.

The blower used for this application is the ACI VLB5/3. This unit is based upon an inside-out motor with the rotor on the outside driving a forward bladed impeller.

The blower with its forward curved blades is a compact efficient unit, delivering high air volumes at high pressure, the precise characteristics required for this application.

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Olympic high voltage provider



Michael Francis, Parsons Brinckerhoff, Arup's Alan Winter, and Kevin McManus of Murphy presented a review of the UK's Lower Lea Valley Cable Tunnels project at the January meeting of the British Tunnelling Society

In the summer of 2005, London won the right to host the 2012 Olympics. Preparations for the construction of the Olympic facilities in East London began in earnest with the undergrounding of the transmission lines that traverses across the site.

The two high voltage transmission lines snake up the Lea Valley from Hackney to West Ham: 25 towers carrying 275kV cables owned by National Grid, who operates high voltage electricity transmission systems for England and Wales; and 22 towers carrying 132kV cables owned by EDF Energy, who operates, manage, maintain, design, construct and control a range of electricity systems in London and the South East of England.

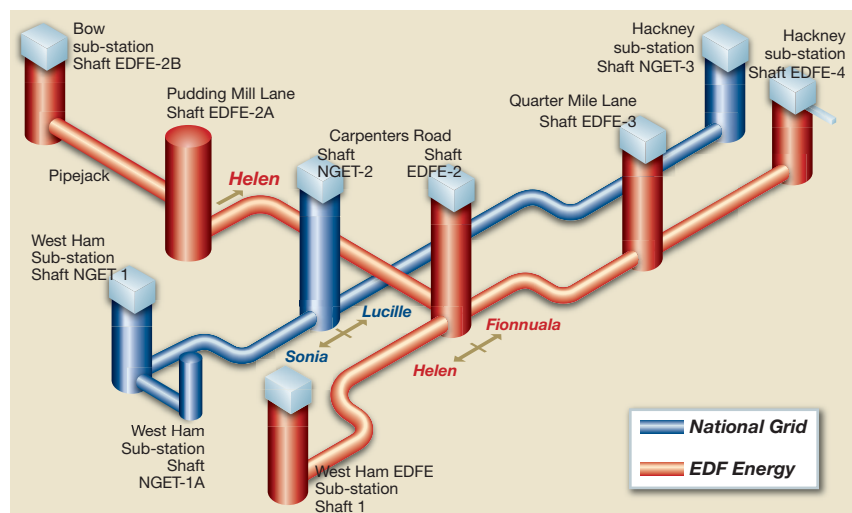
In order to replace the overhead lines (OHL) with systems of equivalent capacity in the tunnel, two circuits, each with three

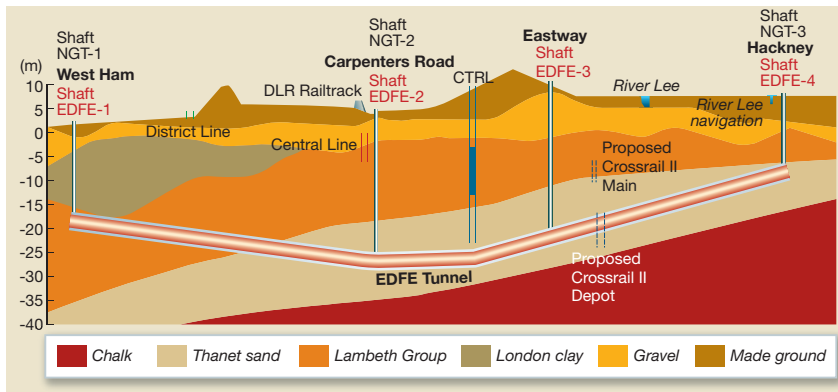
275kV cables were required for National Grid and six circuits, each with three 132kV cables were required for EDF Energy

There are a large number of stakeholders for the project. In the planning stage the London Development Agency (LDA) engaged in discussion with National Grid and EDF Energy. This is when the feasibility study was carried out by KBR, who also undertook a reference design and prepared contract documents. Soon after the 2012 announcement was made, the project came under the directive of the Olympics

Delivery Authority (ODA). The Project Steering Group consists of National Grid, EDF Energy, the Project Director and representatives from the Department for Culture, Media and Sports (DCMS). Their purpose is to discuss matters relating to the progress, major procurement issues, and interface issues. The Project Delivery Team includes Arup who are involved with project management, the Contractors, J Murphy & Sons (JMS), and Detailed Designers, Faber Maunsell. The ODA retained the responsibility of gaining planning consents,

Below: Fig 1 – Layout of the two tunnels





Above: Fig 2 – Longitudinal section of the tunnel geology

land acquisition, and had the support of their in-house legal team. National Grid with Parsons Brinckerhoff (PB) and EDF Energy are part of the team involved in the cable installation and substation upgrades.

Programme

The commencement of the engineering works for the cable tunnel project preceded the award of the 2012 Olympics. Feasibility studies were completed for National Grid and EDF Energy by April 2004. A year later, the reference design and tender documents were completed. This paved the way for the contractor to be appointed two weeks after the award of Olympics to London on the 6 July 2005. The start date on site less than three months after that was remarkable, especially considering the planning permission and land acquisition that needed to be achieved.

It was the programme imperative that drove a lot of the decisions on the designs and methodology for the Lower Lea Valley Cable Tunnels Project. These new cables need to be installed, tested and commissioned prior to any dismantling of the Overhead Lines. When JMS got a letter of intent in September 2005, Charcon, the segment fabricators, and Faber Maunsell were immediately carrying out design of the tunnel and shaft segments as well as the manufacture of moulds. By late 2005 they were producing segments in line with the specification of the project.

Project options

Due to the concern about the high cost of cables in tunnels, there was a need for an exhaustive consideration to determine cost effectiveness. Several options were considered including a multi-utility shared tunnel where National Grid and EDF Energy would have shared a tunnel with other utility companies and diversion of the overhead lines using new towers.

The chosen solution called for a 4.15m i.d. tunnel for National Grid and a 2.82m i.d. tunnel for EDF Energy, respectively. The greatest advantage was that it gave maximum programme security with independent construction programmes which was compatible with the overall Olympics development. Furthermore, cable installation can be carried out from separate work sites at the same time. It also gave National Grid and EDF Energy independence during operation and when maintaining the infrastructure.

Alignment

The two tunnels, 6km each, more or less run parallel to each other. Both National Grid and EDF Energy have Statutory Powers to lay cables under the Highway so the alignment follows public land or the Highway where possible. Central drive shafts for both tunnels were established at Carpenters Road. TBM's were driven in both directions on both tunnels at the same time because of

programme constraints. Four shafts in total were required on EDF tunnel for safe access. Longer distance between shafts on National Grid tunnel was possible based on emergency egress using a monorail vehicle. Hence there are only three main shafts for the National Grid tunnel.

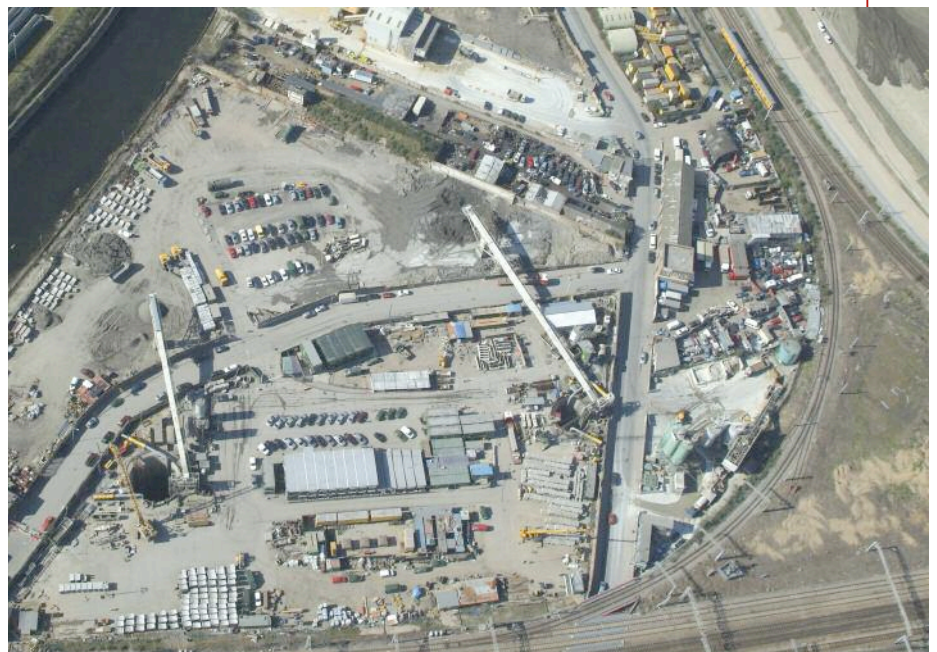
Numerous historical borehole records were used, particularly the CTRL Ground Investigation results. The programme did not permit completion of specific site investigation before tender. As a result, the tender documents were produced with a Geotechnical Report based on historic information. Eleven project specific boreholes were carried out and the results were issued to the contractors at a later stage after the tender period.

The two tunnels were driven more or less at the same level in the Thanet Sands for the majority of the drive and transition up to the Lambeth Group at the West Ham end. The vertical alignment was confined between the Bullhead Beds just above the Chalk and the foundations for the third party structures like the CTRL Station Box. The deepest point was at the Carpenters Road drive shaft at 45m deep below ground level.

Approvals and consents

At the preliminary stage, there was a consensus between the LDA, National Grid and EDF Energy concerning the arrangement of the scheme. There were many other parties that needed to be consulted and informed.

The scheme was one of 21 options formulated to connect the West Ham and Hackney sub-stations. DCMS have conducted an independent audit and the Treasury carried out a Green Book Appraisal.



Right: Aerial shot of the construction site



Above: Shaft construction well underway

An Infrastructure Development Agreement was set up directly between the LDA and the two companies, National Grid and EDF Energy. The shafts, tunnels, head houses, and M&E services were undertaken by a design and construct contract - IChemE Target Cost Contract (Burgundy Book). The target cost with pain and gain share was the means for the Client, ODA, to share financial risk with the Contractor, J Murphy & Sons.

Planning applications were made to the Boroughs of Newham and Hackney before the announcement of the 2012 Olympics. In contrast, Statutory Authorities and Land Owners were only approached after the 2012 announcement was made. A Land Tracker was developed to monitor the advance of the TBM and the status of the acquisition of land permissions. As a result, no delays were experienced due to the lack of consents.

In an urban environment, it is inevitable that the space below ground will be occupied as much as the space above ground. Assets affected by the scheme included:

- Thames Water has the historic Northern Outfall Sewer built by Joseph Bazalgette as well as numerous other assets including old 48" diameter cast iron mains crossing Hackney Marsh
- National Grid: Cast iron gas mains one of

which needed diversion

- Network Rail crossings, including tracks adjacent to the Carpenters Road shaft site
- London Underground above ground tracks for the Central and District Line
- National Grid Sub-station
- EDF Energy Sub-station
- CTRL Station Box

It was the responsibility of the Project Manager to gain access and settlement criteria consents with the aforementioned third parties. Standard contractor's consents like discharge consents remained with the contractor.

Shafts

The two drive shafts at Carpenters Road, 15m i.d. for National Grid and 12.5m i.d. for EDF Energy, were constructed through Thames Gravels overlaying the Lambeth Group and the Thanet Sands. There was around 7m of head in the Thanet Sands with intermediate aquifer in the Lambeth Group and upper aquifer in the gravels. Dry caisson technique was used initially with underpinning down to the Thanet Sands. Needless to say, the use of dewatering was crucial during the construction of the shafts. WJ Groundwater, a specialist dewatering sub-contractors was brought in for the task.

In the variable intermediate aquifer in the Lambeth Group, ejector wells were installed before shaft sinking to permit a rapid start. Deep wells were also established penetrating into the chalk to underdrain the Thanet Sands, however there the programme did not permit long term use of these wells. Local vacuum well points was considered to be a contingency for dewatering the Thanet Sands.

Despite all of the above dewatering systems being in place, JMS started shaft sinking without ground water control. A railway embankment is adjacent to the shaft site and Network Rail had not given permission to switch on the dewatering. As

the excavation reached the Lambeth Group, there was an inflow of water. To keep on track with the tight programme, JMS proceeded sinking the shaft by wet caisson. However, the silt in the Lambeth Group slowed the shaft sinking process. Finally when the consents were gained from Network Rail, the ejector wells, together with the deep wells were activated with some effect, however the delayed groundwater control was not enough to alleviate the problems.

In comparable conditions at Canary Wharf and on the CTRL project, they had a year to lower the water level in the Thanet Sands by deep wells. The Lower Lea Valley team had just ten days. JMS and WJ Groundwater jointly developed an integrated approach to groundwater control so that shafts could be built plate by plate by underpinning and the local well points can be installed progressively. A ring main was attached to the well points cast into the segments. Using this method, the shaft was successfully sunk through the Thanet Sands.

It was a different story for EDF Energy's Quarter Mile Lane Shaft. The water level could not be lowered to the designed formation level even with the array of vacuum well points. Although the horizontal alignment of the tunnel was fixed, the vertical alignment was not. This was used to the advantage by saving programme damaging delays by raising the formation level of the shaft to eliminate the need to lower the groundwater level to such a level.

The construction of EDF Energy's reception shaft at Hackney is also worth mentioning. The shaft was constructed as a wet caisson but soon hit difficulty in dense gravels. The clock was ticking as the EPBM was rapidly approaching the shaft. A secant pile wall was constructed inside the shaft to

Below: The vertical conveyer



QUESTIONS FROM THE FLOOR

Tony Gee (Mott MacDonald) asked what volume loss was achieved for the tunnel drives and also how well the vertical conveyors performed. Kevin McManus responded that an average volume loss of 0.7% was achieved. The vertical conveyor, overall, performed very well. There was a concern that the conveyors were able to tackle everything that was offered to them.

Tony Swain (UCL) asked why IChemE, Burgundy was used for the Civil Works Contract instead of NEC. Michael Francis responded that since the early stages, the IChemE contract was seen as the one that National Grid and EDF Energy were

comfortable with.

Tim Hughes asked how the Civil Works Contract worked in practice. Kevin McManus responded that there were no problems on the commercial side for JMS.

John Murphy (Tubelines) asked whether the availability of labour impacted on the project. Kevin McManus said it was a very intensive job. Once the TBMs were ready to go, there was a ramping up of labour but there was enough skilled labour around. In the summer of 2006, the TBMs in the Lower Lea Valley Cable Tunnels Project represented 80% of the large diameter UK TBM market.

Rapporteur: Nao Otsubo

enable the construction of the shaft to the required depth. Within 36 hours of the solution being agreed, specialist sub-contractors were called in and secant piles were installed. Consequently, this has reduced the shaft i.d. from the original 10.5m to 7.5m, enough to accommodate the extraction of the EPBM. In the end, there was a slight delay for the EPBM breakthrough but with no adverse effect on the overall programme.

Tunnel

EPBM was the best machine for the job with its proven record of tunnelling in the ground condition expected in the East London area on CTRL and projects for Thames Water. TBMs for the 2.82m i.d. EDF Energy tunnels, Fionnula and Helen were refurbished and fitted with new heads by J Murphy. The other two TBM's, Lucille and Sonia, for the 4.15m i.d. National Grid tunnels, had been used in Los Angeles and were refurbished in Canada by Lovat. An 8.2MVA power supply was installed to power these machines. The four cable extensions a week allowed high voltage switching manoeuvres.

The push for the programme meant that after the initial steep learning curve, JMS had to keep the TBM's constantly working at their optimum. The muck was transported away from the face of the tunnel using rail trains. Vertical conveyors were used at the drive shaft. This reduced the number of windings in the shaft and provided quicker turnaround of the muck wagons. Overhead conveyors extended to a muck holding area across Warton Road. This layout kept the yard free from vehicle movements.

A year after London winning the 2012 Olympics total excavation advance on the four faces was in excess of 600m on a consistent basis. This was a great achievement. All four EPBM's performed magnificently in the Thanet Sand and the Lambeth Group.

The civil aspects of the shaft and the tunnel are now complete. Currently, the brackets are being mounted in the tunnels for the preparation of the cable installation.

Summary

The Lower Lea Valley Cable Tunnels Project was exposed to the programme pressure from the early planning stage. The flexible



Above: Members of the crew celebrate breakthrough

and committed approach from the stakeholders, together with the implementation of active risk management, has benefited the project immensely.

The construction of the tunnels and the shafts are on time and on budget. The successful completion of the cable tunnels will pave the way for the construction of the Olympic facilities and ultimately, for the successful running of the 2012 London Olympic Games.

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Sprayed concrete success

Primarily areas of development over recent years in the field of sprayed concrete include improvement in operator safety, such as by using non-toxic accelerators and reducing dust, better early-age concrete performance, wider use of fibre reinforcement (polymer artificial fibres as well as steel), better operator training, and also mechanised application further developing into robotic devices with sophisticated controls.

In addition, modified sprayed concrete mixes and lining designs have been developed to achieve the desirable properties for fire resistance and waterproofing or control.

In the absence of sprayed concrete design standards, albeit with agreed testing procedures (see EFNARC European Specification for Sprayed Concrete & European Standards), specifications are dependent on designer preferences, which manufacturers

and contractors have to meet. Product developments, both in materials and applicators, have to some extent permitted safety factors to be increased or economies to be made as efficient application and performance can now be more assured.

For example 'shadows' and possible voids should be a thing of the past when using correctly programmed robotic equipment with swivel nozzles to work from all relevant angles onto the surface being lined, including any installed reinforcement. Correct mixing without separation in transmission is also necessary to achieve a homogenous lining.

Ingredients

A range of safe concrete additives is available from leading suppliers to achieve the required properties of sprayed concrete both in placement and curing. These include retarders during transport, plasticisers, silica fume for increased density and waterproofing, and accelerators for binding to the target surface and early load bearing.

Mapei offers a range of over nine

Tunnel support and lining methods involving sprayed concrete have had more than their share of controversy. Technical journalist, Maurice Jones, looks at this maturing technology with practitioners and suppliers

Mapequick liquid accelerators for wet-mix and dry shotcrete mixes. A recent introduction applicable to the repair of tunnels is Mapegrout T60 sprayed concrete mix. Tests have been carried out of the material used in conjunction with Mapequick AF1000 alkali-free accelerator to avoid slump and achieve a build-up of 150mm in a single application.

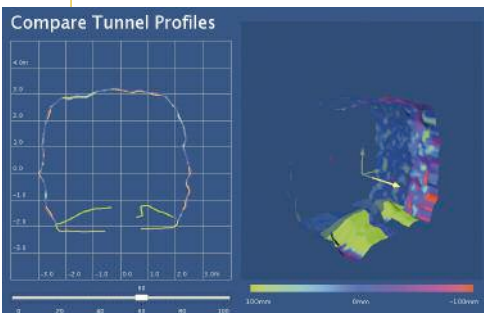
Two layers of small-diameter reinforcing mesh were employed. The last 20mm thickness was sprayed without accelerator to form a floated face finish. Mapegrout T60 is sulphate-resistant, thixotropic and fibre-reinforced mortar for wet or dry-process application. Appropriate accelerator dosage can achieve the required curing time from instant to over 24 hours.

The costs questions

Something that is looming large in the minds of contractors, but has yet to make an impact with most design engineers, is the effect of soaring raw materials and energy costs. The latter, of course, affect all aspects of manufacturing and contracting.

Steel has soared in price over recent months, and it is a world-wide phenomena affected by seemingly remote factors such as the shortage of electrical power in China due to a particularly severe winter, and the consequent need to close arc furnaces, resulting in substantial loss in production. As for the steel fibre reinforcement of sprayed concrete, it is as much the uncertainty of price and supply as the higher cost that can play havoc with contract estimation unless a very large purchase contingency has been built in.

A representative of a major steel fibre supplier claimed: "We have softened the blow as much as we can by increasing the price for fibre by US\$80/t twice in two months, rather than US\$160-200/t in one go, as suppliers of rebar have done. But



Left: Screen dump from the Meyco-Amberg profile control monitoring system used in the Logica automated spraying system

Below: One of six BASF Meyco Potenza mobile spraying systems used in the Lainzer rail tunnel in Vienna, Austria



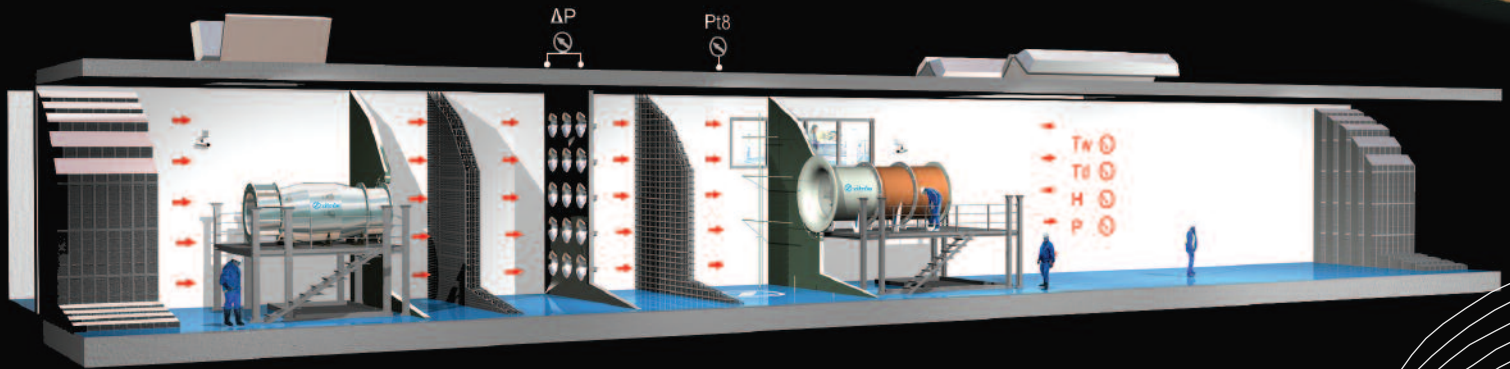
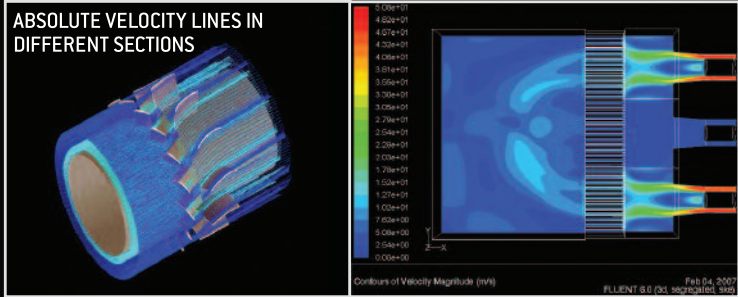
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Rodrigo Caballero, BASF CC Chile

Above: Glass panels over rough sprayed concrete on Line 4 of the Santiago Metro

normally we cannot afford to guarantee price for longer than a month.”

Delays in shipping and the world-wide price increases mean there is little point in looking further afield unless special negotiation is successful. According to a trade bulletin the world rebar price hit US\$764/t this month whilst rebar prices in China have also hit record prices, Turkish scrap prices rose sharply and export rebar hit US\$880/t, and suppliers in Southern Europe and Japan all lifted prices the previous month for rebar and wire rod.

Our source said, “Cute users have been buying up stocks of fibre and we are virtually cleared out, with production going straight out the door. We can fulfil smaller short-term orders but long-term (over a month) fixed-price orders cannot be accepted without special approval and a substantial project. All the indications are that this is not a temporary condition, and we will all have to manage high prices for the foreseeable future. Whilst most contractors have taken the current situation on board as they are directly affected by the increased prices, realisation has yet to filter through to most consulting engineers, perhaps because they consider it to be a contractors’ problem. Unlike previous occasions when steel went up in price, the synthetic fibre suppliers are also affected due to increases in the price of petrochemical products like polymers.”

Vice-president of the ITA, Eivind Grov, and research manager for rock and soil mechanics with SINTEF of Norway says he is not too concerned about the increasing steel costs, insofar as they are related to sprayed concrete use, although there is a shortage of steel for rock bolts, he reports.

“I don’t think the current situation will be to the disfavour of sprayed concrete as a permanent lining,” he said. “The use of massive cast concrete is likely to suffer more because of the greater amounts of materials used.”

A downstream supplier of fibre-containing mixes commented, “We are holding our prices so far, and have not been pushed yet. There is high demand though from tunnelling and mining with a boom in rock support, especially in Asian infrastructure projects.”

Whilst steel-fibre-reinforced sprayed concrete, for example, is relatively light on materials affected by soaring prices, other forms of necessary reinforcement can greatly increase the cost of the whole lining.

Welded mesh and rockbolts are common ways of improving the strength of the lining and the surrounding ground, whilst lattice girders are commonly used in poor ground. Not only are they relatively economical in the use of steel, their use in preference to standard girder sections means that they interfere less with the application of the sprayed concrete.

Heintzmann lattice girders are available in triangular and rectangular sections for primary shotcrete lining. A ‘strong wave’ triangular section utilises a thicker steel chord on the apex. Lengths and bending radii are produced as required with connections by butt plates or overlapping. In addition the Heintzmann Group offers yielding TH-arches for extreme conditions, which, when reverse bent, give only a small spray shadow.

Similarly, Pantex lattice girders supplied by the Alwag division of DSI and designed by TAT, are available in arches of triangular and rectangular sections of different construction. ‘Wallplate beams’ for connecting arches longitudinally are also available. Alwag says that Pantex lattice girders have been tested for stability and load bearing even when not bonded into the shotcrete layer. Once covered in concrete the lattice structure in a tunnel lining allows porous zones and ‘shadows’ to be avoided for better load bearing and water-flow deterrence. The good bond between lattice girders and well-placed sprayed concrete allows the girder arches to be integrated into the design of the sprayed concrete.

Going back to steel reinforcement fibres, there is claimed to be a clear case for not buying cheap, even setting aside durability issues. Bekaert, for example, offers two types of premium Dramix fibres for underground concrete spraying; the RC-65/35-BN and the ZP 305. Bekaert’s John

Right: Elevated walkway on Line 4 of the Santiago Metro, in Chile

Greenhalgh commented: “Our premium fibres are usually more expensive but careful use can save money. Use of fibres with a lower aspect ratio (than the 64 of the RC-65/35-BN Bekaert fibre) can mean you need more to get the same performance – say 35kg/m³ instead of 20kg/m² with ours, resulting in a total cost increase; added to which we have a long-term commitment to performance.”

Current topics

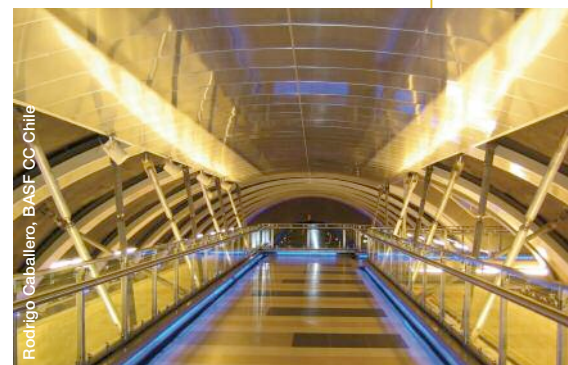
Papers and presentations scheduled for the Fifth International Symposium on Sprayed Concrete, to be held in Lillehammer, Norway, on 22-24 April reflect current developments in underground sprayed concrete technology.

Anders Ansell of Sweden’s KTH research body will present practical guidelines for shotcrete use on rock exposed to blasting, whilst Ø Bjontegaard of Norway will cover testing of the energy absorption of fibre-reinforced sprayed concrete. Ansell will also present with Jan Holmgren on tests on restrained shrinkage of shotcrete with steel fibres and glass fibres.

A wide range of conditions for sprayed concrete use are recognised from around the world, naturally including a paper on the use of wet-mix sprayed concrete in permafrost rock from T Beck of Norway. Another environmental topic from Norway, by Per Hagelia of the Norwegian Public Roads Administration is the deterioration of steel-fibre-reinforced sprayed concrete by the action of sulphate-enriched groundwaters and bacteria.

There are to be other papers covering ingredient performance considerations, especially on accelerators and reinforcement fibres, although there have been few substantial developments in the ingredients themselves in recent years. Performance studies and the most effective use of sprayed concrete are the main foci of development, with quite a variation in expertise between countries.

Eivind Grov has commented that Norway and other Scandinavian countries, who were the front-runners in the development and



Rodrigo Caballero, BASF CC Chile

application of wet-mix shotcrete, appear somehow to be caught up by the rapid development of shotcrete in other countries. This may be due to the general rock conditions there but Grov thinks it is more a matter of approach. "From when I attended a conference in Tasmania in 2001 I noticed a difference. The people there have really been quite advanced in the use of sprayed concrete. They have a thorough theoretical approach, whereas the Scandinavian approach has always been empirical. We can improve by the theoretical approach to design, and in other aspects of sprayed concrete. We are developing tests to learn more about the abilities of sprayed concrete and in the application of materials knowledge. Fibres are being tested in many countries. Taking the best from both approaches will make sprayed concrete a winner, which is indeed required in the tunnelling industry."

"We in Scandinavia, including the Norwegian tunnelling industry, may be becoming too laid-back. We will try to 'kick the legs' of tunnellers to prevent them from falling asleep and keep up the drive in improving, testing and documenting shotcrete application. This is important for all participants in the tunnelling industry."

Of course there will also be reports on the work of ITA Working Group WG12 from Animateur Tarcisio Celestino, Themag Engeharia, Brazil and former Animateur Knut Garshol, now of the USA, who will present the recent "State-of-the-art report on shotcrete" prepared by the working group members, collecting practices from the member nations of ITA.

Hindhead Tunnel

The UK's 1.9km Hindhead Tunnel will probably use one of the most advanced sprayed concrete linings to date in that the process will be even more closely tied to careful profile excavation, as far as ground conditions will allow. Excavation with a Liebherr backhoe plus sprayed concrete lining using three BASF Meyco Logica robotic spraying units (see below) has been selected rather than a TBM. The key is working close to the planned profile using Amberg 3-D profile monitoring integrated with the machinery control systems.

Application

The Meyco Division of BASF offers a wide range of concrete spraying equipment for all sizes of tunnel, portals and various site conditions. The Meyco Potenza mobile spray unit has been developed from the Spraymobile and retains its main features but with central power and control. These include the Meyco wet spraying machine, TDC dosing system, Robojet manipulator

and a 4x4 Dieci chassis. Six Potenza units have been delivered for use on the 6.5km high-speed rail Lainzer Tunnel, in Vienna, Austria. The main purpose is producing a thick primary lining in unconsolidated rock.

The Logica is Meyco's most technically advanced system with robotic control to maintain an accurate profile and lining thickness. The hardware has been further developed with automatic control and georeferencing. The system scans the surface of the tunnel with external georeferencing tracked by a total station. This prepares a 3-D model of the tunnel section to be lined. The concrete spraying is controlled automatically by robotics integrated into the spray vehicle. Three units are to be used at Hindhead.

CIFA has two main mobile sprayed concrete systems; the self-propelled, twin-axle CSS-3, and the PCS 209 single-axle trailer unit. The former carries its own water and liquid accelerator tanks. The Uniflux EAS 2 accelerator dosing system is configurable in two capacities to meet different flow rates, and has electronic control management. Depending on the boom configuration the CSS-3 can cover tunnels from 2 to 16m radius. The remotely operated nozzle head swivels to 45 deg either side of the longitudinal axis and through 180 deg in the vertical plan.

The PCS 209 trailer can be towed at 6km/h, powered by diesel or electric drive.

Sealing

As a rapid means of surface stabilisation on rock or soil UGC International (BASF Europe) introduced Masterseal 845A/855 thin spray-on liner (TSL). This provides weathering protection and well as acting as a base layer for further sprayed concrete lining with which it forms a good bond to allow single-shell linings. Curing takes place within a few hours. It is generally only one part of a final support system and chiefly aimed at mining applications. Another grade of Masterseal is used in tunnels primarily for waterproofing. Masterseal uses dry powder spray pumps with water added at the nozzle.

Aesthetic support

Under discussion is the acceptable finish of a final sprayed concrete lining. Is a rough finish acceptable for public access tunnels and others where lighting is important? Can the finish be made more acceptable by decorative panels or additional coatings? Or is it necessary to smooth the surface by an additional layer or mechanical process?

Former head of technical management of BASF UGC International, Ross Dimmock, reports that the use of sprayed concrete lining is of growing importance and interest in underground urban railway construction



Above: Spraying the face on the Gotthard HSR Tunnel in Switzerland

for permanent as well as temporary lining, due to improved capabilities. The finish is naturally a consideration. "In the Santiago Metro, Chile, for example, there are huge spaces supported with a permanent sprayed concrete and membrane sandwich construction. The finish is 'as sprayed' and over-painted. There are also decorative panels including glass sections and fascias. The Helsinki Metro also has a sprayed finish that looks really modern."

"A drawback of a smooth finish is that it shows imperfections such as cracks and seepage more clearly," says Dimmock.

Neither should a spray finish in running tunnels be a problem, even for high-speed railways. "With AlpTransit (in Switzerland) it was thought that eddy currents in the air could be a problem in deciding between a cast or sprayed final lining," continues Dimmock. "It was found, however, that only the tunnel services presented a potential problem as long as the sprayed concrete was applied to the correct profile."

"A two-way perspective is necessary," commented Grov. "It involves two different things – one related to the need for rock support and the other to architectural aesthetics. It's a long story. In Scandinavia we are utilising the capacity of the rock itself, only supplementing its self-standing capacity until you have sufficient. Other countries use it as a temporary phase only and add another permanent lining to finish. In Norway we try the 'self-standing' approach for all sorts of ground, but there is a limit. We can also use sprayed concrete followed by bulk cast concrete, but that amount is very small. There are a large number of projects each year that use no concrete at all, with cast-in-place used in very bad ground only. We always try to find a support solution that will replace cast-in-place concrete, such as by using steel-fibre-reinforced shotcrete."

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Dates & Events

10-12 APRIL IS-Shanghai 2008 Shanghai, China

The 6th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, is organised by Tongji University under the auspices of the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE). For more on this symposium on booming China; Contact: www.tc28-shanghai.org

22-24 APRIL 5th International Symposium on Sprayed Concrete - Wet Mix Lillehammer, Norway

Organised by the Norwegian Concrete Association, main themes will be design, construction and durability of wet-mix sprayed concrete. Results from the Hanekleiv investigations, will also be presented. Contact: info@sprayedconcrete.no; Web: www.sprayedconcrete.no

4-7 MAY 13th Australian Tunnelling Conference Melbourne, Australia

"Engineering in a changing environment" is the topic of the 2008 Australasian Tunnelling Society conference. The present buoyant conditions in civil infrastructure and mining Australia and New Zealand promise a great programme. Contact: AusIMM; email: dedwards@ausimm.com.au; web: www.atstunnellingconference2008.com

20-22 MAY Intertunnel 2008 Turin, Italy

This bi-annual international exhibition will focus on major projects in Italy. The show promises to be an excellent networking environment, bringing together experience from tunnelling projects in many countries. Contact: Olivia Griscelli, exhibition director; email: intertunnel@mackbrooks.com; web: www.intertunnel.com

29-30 MAY Second Seminar of CPT "Tunnels and Underground Works in Portugal", Lisbon, Portugal

Organised by the Portuguese Committee on Tunnelling (CPT). Contact: Catarina Luis. Tel: +351 218443859; email: spg@lnec.pt; web: www.spgeotecnica.pt/cptuneis

3-6 JUNE International No-Dig 2008 Moscow, Russia

Hosted by the International Society for Trenchless Technology and co-hosted with the Russian Society for Trenchless Technology, this will be the first ISTT event to be held in Russia. Contact: ISTT; Tel: +44 20 7259 6755; email: info@istt.co.uk; Web: www.istt.com

7-11 JUNE North American Tunneling Conference San Francisco, USA

The 2008 NAT Conference will be held at the Hyatt Regency, San Francisco. Conference programme and registration details are now

available on the UCA of SME web site. Contact: Society for Mining, Metallurgy and Exploration (SME); www.smenet.org

10-12 JUNE Swiss Tunnel Congress 2008 Luzern, Switzerland

The annual review organised by the Swiss Tunnelling Society includes a lecture on grouting as a support measure during excavation, papers from the Gotthard Base Tunnel, and an excursion to the Gotthard Tunnel. Contact: Thomi Bräm; Tel: +44 56 2002333; email: sia-fgu@swisstunnel.ch; web: www.swisstunnel.ch

23-25 JUNE 2nd Brazilian Congress of Tunnels and Underground Structures, Sao Paulo

The conference will cover 17 tunnelling themes and focus on recent works in the area and will take place at the Centro Fecomercio de Eventos, Sao Paulo. Contact: Tel: +55 11 3522 8164; email: 2cbt@acquacon.com.br

25-27 AUGUST Wireless Communication in Underground & Confined Areas Québec, Canada

The second international conference focusing on original research, innovative applications, or analysis of experiments on site, relating to telecommunications in an underground environment (tunnels, metros, mines, etc). Contact: web: www.icwcuca.ca

17-18 SEPTEMBER IUT'08 5th International Underground and Tunnel Fair, Sargans, Switzerland

Time to go underground again, at what is becoming one of the calendar's premium events. Held in the unique setting of Switzerland's Hagerbach Gallery. On 19 September, technical tours will take place. Contact: web: www.iut.ch

22-27 SEPTEMBER 2008 ITA World Tunnel Congress Agra, India

The 34th ITA General Assembly and Congress will be held at the Hotel Jaypee Palace, in Agra, India. In view of the large scale tunnelling works to be undertaken in the near future in India, there is much scope for agencies within as well as outside the country, to demonstrate their capabilities. Contact: CBIP; email: sunil@cpib.org; web: www.wtc2008.org

23-26 SEPTEMBER InnoTrans 2008 Berlin, Germany

This international convention and trade fair for transport technology, including railway infrastructure, interiors, public transport and tunnel construction, has become a popular addition to the event calendar. Contact: Messe Berlin; Web: www.innotrans.com

6-8 OCTOBER International Congress 'Building Underground for the future,' Monaco

Organised by the Association Francais des Tunnels et de l'Espace Souterrain (AFTES), the three day event will consider the future use of the underground space with papers presented from all walks of the tunnelling spectrum. Contact: AFTES; email: aftes@snc.fr; web: www.aftes.asso.fr

BRITISH TUNNELLING SOCIETY

17 APR: Harding Lecture - Risk Management

The annual Harding lecture this year is presented by Arnold Dix, Queensland University of Technology, International Tunnel Insurance Group. 6pm start, at the ICE, Westminster, London.

15 MAY: Annual General Meeting followed by

"The Arrowhead Tunnel"

Presented by Brian Fulcher and Mike Bell. 6pm start, at the ICE, Westminster, London.

22-24 OCTOBER Underground Infrastructure of Urban Areas, Wroclaw, Poland

The conference is organised by the Urban Engineering division of the Institute of Civil Engineering, Wroclaw University of Technology, in association with the ITA, ISTT and EFUC (European Forum on Underground Construction). Contact: tel: +48 71 320 2914; email: andrzej.kolonko@pwr.wroc.pl; web: www.bliw.wroc.pl/uiua/2008

10-12 NOVEMBER ICDE 2008, Challenges and Risk Management of Underground Construction, Singapore

The International Conference on Deep Excavations (ICDE) is an ITA sponsored event organised by TUCSS. It aims to be a forum for contractors, engineers and owners to share and discuss experience. Contact: TUCSS; email: info@tucss.org.sg

23-28 MAY 2009 2009 ITA World Tunnel Congress Budapest, Hungary

The 35th ITA General Assembly and Congress will be held in Budapest. With a large amount of tunnelling underway and in planning, the organisers are confident it will be a successful event. Contact: Diamond Congress; email: secretariat@wtc2009.org; web: www.wtc2009.org

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Tris Thomas, 'Tunnels & Tunnelling International', Wilmington House, Maidstone Road, Sidcup, Kent DA14 5HZ, United Kingdom.

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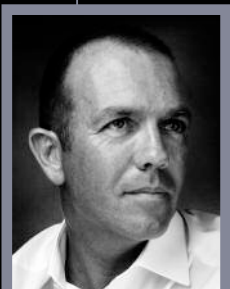
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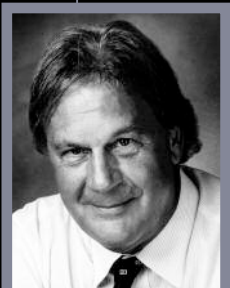
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