MARCH 2010

tunnels & tunnelling INTERNATIONAL

BAUMA TRADE SHOW

T&TI looks at what Bauma can tell us about the current market and what not to miss at the show

SHOTCRETE TECHNOLOGY

A look at the developments in sprayed concrete aplications

BREAKTHROUGH SERVICES

Beijing Metro

6.3 metre diameter EPB TBM

Tunnel Boring Machines

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Contents

FRONT COVER: The giant Robbins EPB TBM in Mexico City's Downtown Federal District is the first of its kind to be assembled entirely at the jobsite (p28).

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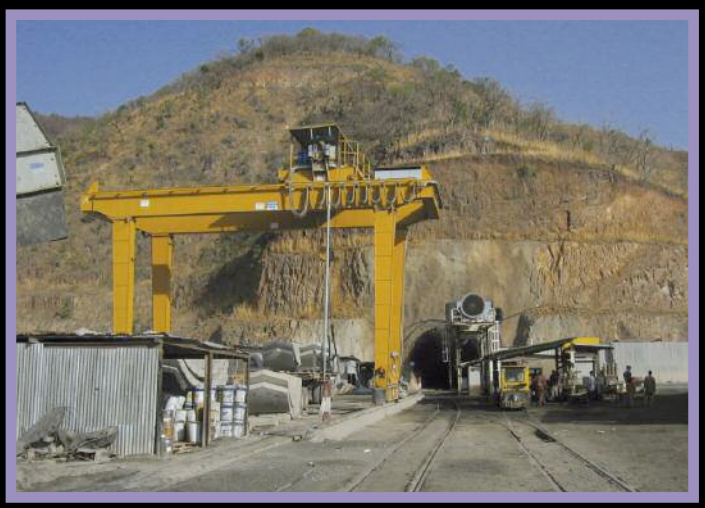
BAUMA

7

One of the portals to the Gilgel Gibe II that suffered a collapse last month in Ethiopia



SHOTCRETE TECHNOLOGY

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A Putzmeister-Sika SPM 500 PC wet-spray concrete manipulator

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From the horses mouth

This is the comment I did not want to write. I had planned to discuss what the highs and lows of Bauma can tell us about the market in general, but first I feel we should nullify the puerile rumours that appear to be circulating within our industry; an irritating itch that we can not help but scratch.

T&T is not closing. There have never been any plans to close the magazine and any attempts to portray otherwise are the result of childish ambitions to disable a much loved brand. There, I've got that off my chest, now back to the important stuff: what we ARE doing.

In fact, in the past six months *T&T* has gone through a greater expansion than in any period in its 40-year history. We have a strong editorial team with well over 100 years publishing experience and some 50 years engineering experience. This expanded team is allowing us to up the number of *T&TI* issues you'll be receiving, rather than the usual 10 regular issues a year with two data issues, you'll be getting 12 regular issues with data supplements.

T&T goes to the heart of the tunnelling industry and the association with the *British Tunnelling Society* remains as strong as ever. In this way, I am pleased to announce that once again *T&T* and the *BTS* are partnering on a conference, which will be held on 28 September at the Institute of Civil Engineers in London.

But *T&TI* is a global magazine. To reflect our international approach we have joined forces with other tunnelling bodies round the world on supplements that go to the heart of their cause, starting with the German Engineering Federation (VDMA) on our Bauma supplement, which you'll find in your next issue. And in May we will be partnering with the International Tunnelling Association to bring you a World Tunnel Congress supplement that will include a look at tunnelling activity in each region.

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Tunnelsonline.info has gone through some great advances in the past few months. We have started delivering the latest news to you every day through the website and additionally through a weekly newsletter sent to some 15,000 readers.

That's not the limits of our plans for the website. Later this year we will be launching a brand new online offering that promises to give you everything the industry has been looking for, from extensive historical archives to the latest news, jobs and equipment. And in partnership with *T&T* publisher World Market Intelligence we are already able to offer the largest, most detailed database of proposed, active and completed tunnelling projects round the world.

One more development that will not slip past you, *T&TI* is changing its look, all will be revealed next month.

T&T has proven itself time and again for the past 40 years and that is not going to stop on my watch.

Jon Young

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T&T is not closing. There have never been any plans to close the magazine and any attempts to portray otherwise are nothing but devious and malicious rumours spread only to further the fortunes of those initiating them.

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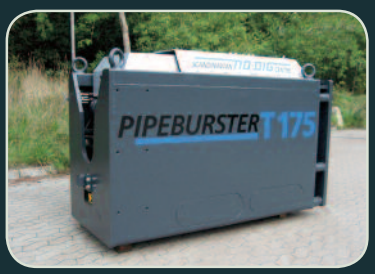

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Gilgel Gibe 2 collapse

The collapse of the Gilgel Gibe II headrace tunnel in Ethiopia last month was caused by extremely high rock and mud pressure of a major fault associated with loose cyclopic dolerite blocks and round boulders, a Seli spokesperson told T&TI.

"One possibility is that the faulty ground (high pressure mud mix with round boulders) in this area was separated from the tunnel by a relatively thin diaphragm of a fractured dolerite dyke. When mud pressure was able to break the diaphragm, a sudden concentrated and dynamic load of mud and blocks acted on the tunnel section causing the damage," she said.

However, consultant engineer Christopher Douglas of Electro Consult told reporters at a press conference on 12 February, "It is still too early to say whether what happened was because of geological reasons."

The client Ethiopian Electric Power Corporation (EEPCO) will leave Salini, Seli and a team of expert consultants to investigate the exact cause of the collapse and the repair measures needed to see the plant fully operational.

"The event effected only 15m of tunnel out of a total of 26,000m and there is no doubt that the problem will be solved in a minimal period of time and at minimal cost," the Seli spokesperson told T&TI.

She continued, "Briefly the works to be performed are tunnel cleaning, repair and reinforcement of 15m of partially-damaged segments, and final consolidation grouting. An alternative short bypass is also a viable solution currently under consideration."

Above: Portal to Gilgel Gibe II

Seli expected the plant to remain closed for two to three months for repair.

The collapse happened in a water-passage tunnel in the €374M (US$512.5M) project, Ethiopia's biggest power plant. The project channels the water discharged from the Gilgel Gibe I Dam through a long tunnel and a steep drop directly to the valley of the Omo River.

China collapse leads to trial

Ten people will go on trial in China for the subway tunnel collapse last year in East China that killed 21 construction workers.

The collapse happened last November in the tunnel that was under construction in Hangzhou, capital of Zheijang Province.

Investigations by the Work Safety Supervision Administration of Zheijang blamed the collapse on violations of construction rules, problems in the supporting systems and moulding procedures, and project monitoring failure.

The ten defendants include the general manager, the chief engineer quality officer of the project, two officials with the contracted monitoring company, two employees of contractor Fourth Bureau of the China Civil Engineering Group, one officer from Hanghzhou Subway Group, and two officials from Hanghzou's construction quality supervision station.

Eleven other people, mostly officials with the project contractor, received administrative punishment, according to local authorities.

The collapse cost 49.6M yuan (US$7.3M) in economic loss and triggered safety overhauls in subway projects all over China.

Clem7 tunnel

The Clem7 tunnel in Queensland will be completed early this month, seven months ahead of schedule.

The 6.8km long tunnel will link Bowen Hills and Woolloongabba.

As the final touches are put on the AU$3 bn (US$2.7bn) Clem7, testing of the tunnel's safety systems is under way ahead of its opening later this month.

A total of 212 cameras will monitor the tunnel, pinpointing all potential hazards before they occur.

Operators will then be able to assess the incident, before employing safety procedures ranging from closing lanes to emergency evacuations.

The Clem7 will give Brisbane a much needed additional river crossing and save motorists up to 24 sets of traffic lights and an average of 15 minutes each way in peak hour.

It is expected that around 60,000 motorists will use the tunnel each day once the AU$4.28-a-trip (US$3.85) toll starts, with that figure rising to 100,000 after 18 months.

Qatar to construct subsea tunnel

Qatar will go ahead with plans for a 12km subsea tunnel, it was announced last month.

The tunnel will link Doha's new airport, due for completion in 2011, with Lusail and West Bay, the country's financial centre. The estimated cost of the tunnel is US$1bn.

Danish engineering consultants Cowi submitted in February a feasibility study and a preliminary concept design to the client, Qatar's Ministry of Municipality of Urban Planning. The plans will await approval from the Qatari government.

When asked at a recent event in Doha whether the project would cost more than US$1bn, acting manager of the design department at Qatar's Public Works Authority said, "Yes, definitely. A lot more," local media reported.

Details of the project first emerged in 2008 when Cowi won the contract to carry out the feasibility study. Other options considered for the link were a bridge across Doha Bay and a tunnel running under the Corniche, Doha's waterfront promenade.

Illegal borers caught out

A 12-kilometre water tunnel in India is currently undergoing repair work after two men damaged the main pipeline while drilling an illegal bore-well.

The incident came to light when the residents noticed water leakage last month in the area of Malad.

Initially, locals thought a pipeline burst caused the rupture. However, when Brihanmumbai Municipal Corporation (BMC) officials investigated the leakage they found that Vilas Kadam, the plot owner and Jagdish Talreja, the contractor, punctured the pipeline.

After causing the burst, both men attempted to seal the crack but failed to stop the tunnel from leaking out. Now it is feared that the water has weakened the foundations of several buildings nearby.

Chief hydraulic engineer of the tunnel Vinay Deshpande told T&TI, "The water has already begun causing soil erosion which has formed huge cavities under the ground, making the surface hollow. If this continues, the structures may collapse."

Local authorities in Malad are now considering emptying the five year old tunnel to repair the damage. However, the work has been held off temporarily as the repair work would cut the water supply between the towns of Bandra and Goregaon.

Deshpande added, "We have temporarily resolved the problem by inserting a wooden plug to stop the leakage since the puncture. Two days ago we re-excavated the area, and passed a camera through the tunnel. We now know that the repair work could take up to six weeks."

Repairs to the Malad water tunnel will be a costly affair for the cash-strapped BMC, as specially designed pumps will have to be hired to abstract water from the tunnel which is 250-300 feet deep, and 6 metres in diameter.

Deshpande told T&TI, "I estimate that the cost will come to around Rs5M (US$108M) to resolve the leakage. The repairs will be carried out by water experts, tunnelling masters and hydraulic engineers."

The BMC is now implementing stricter measures on bore well applications by surveying the area before granting permission. Anyone caught digging without permission will be prosecuted.

With regards to Kadam and Talreja, Deshpande told T&TI, "The police have registered an FIR (First Information Report) against them. Both culprits will be prosecuted in the court and penalised for their actions."

Illegal border tunnel discovered

Mexican soldiers in February found an illegal underground tunnel at the border with the United States. The 15m long, 1m wide unfinished tunnel ran from customs offices at the Otay Mesa in Tijuana, Mexico, toward the U.S. border.

The design of the tunnel is similar to others used by drug smugglers and human traffickers in the area. When discovered, the tunnel was 50m away from reaching the U.S. side of the border.

The tunnel was the fifth discovered at the border crossing in less than a year.

TBMs assembled for Mexico water tunnel

The manufacture of the first TBM for Mexico City's Emisor Oriente water tunnel project was celebrated last month with the turning of the cutterhead at the Corpus Christie, Texas factory. The 8.93 diameter machine will be used to bore the 62 km long wastewater line that will prevent flooding and increase capacity by its completion in 2012.

The three EPBs from Robbins are being assembled in the Kiewit plant in Corpus Christie with mechanical components locally manufactured and major steel components shipped from the Robbins factory in China. From Texas the machines will be shipped via freighter to Veracruz, then by truck to three different shaft launching sites in spring.

"These machines are specially designed for the unique geology of Mexico. They have been engineered to handle a face of mostly clay with some basalt rock. Their flexible design is a great advantage to the project," said José Luís Luege Tamargo, director of the National Water Commission (Conagua), also the project owner.

Located in the Valley of Mexico City, the geology of the capital consists of a drained lakebed with clays, interspersed with volcanic rock and boulders from long dormant, buried volcanoes in the area. The TBMs will utilize clay spades and drag bits that can be changed out for 17in (432mm) disc cutters depending on the geology.

Two-stage screw conveyors will help to regulate high water pressures of up to 10 bar—some of the highest pressures EPBs have ever operated under. An initial 900mm diameter ribbon-type screw conveyor will accommodate expected boulders up to 600mm in diameter. Contractor Carso Infraestructura y Construcción, S.A. de C.V.will use the TBMs on lots 3, 4, and 5, each between 9.5 and 9.7 km.

The Emisor Oriente line will use a total of six TBMs, and will add about 150 cubic meters of water per second once complete. The project will operate in parallel with the city's aging main wastewater line, Emisor Central.

Since the central line was built in 1964, Mexico has sunk at the rate of 10 cm annually, causing the drainage system pipe to lose its slope. In addition, the Emisor Central's concrete and rebar walls have been severely degraded by corrosive gases, leaving areas of the city at risk of flooding. "This project is very important for Mexico City," said Jesús Medecigo Castañeda, superintendent of planning and control for Conagua. "We will avoid flooding in the downtown area, increase capacity, and all the water once untreated will now be treated at a nearby plant and reused for irrigation."

Left: The three EPBs are being assembled in Corpus Christie

Second Brenner bore launched, first restarts

The second exploratory tunnel bore at the Brenner Base Tunnel commenced excavation at the start of February, and follows the restart of the first drive from the opposite end after lining repairs needed due to high-pressure groundwater at a fault zone.

With work underway to clear a boulder in unconsolidated rock at the portal, excavation of the 5.7km long exploratory drive from the Innsbruck end of the planned 55km long Austrian-Italian rail link was set to get underway in earnest by the beginning of March. The bore will be excavated by drill and blast.

The package of works being undertaken by the joint venture of Strabag and Porr Tunnelbau is valued at approximately E63M (US$85M), and includes a 2.3km intersecting adit to be bored, also by drill and blast, in the Ahrental area.

At the other end of the scheme, the Seli TBM had advanced a further 665m since it was restarted in December. The 6.3m diameter was recovered from tunnel damage at a fault zone last August, approximately 6.15km into the drive from Aica in Italy.

The double shield TBM was launched in April 2008 and is achieving an average advance of 20m per day through granitic formations of up to UCS 220MPa. However, the 200mm thick concrete segmental rings behind the shield were deformed, and some damaged, when high pressure groundwater up to 27 bar was unexpectedly encountered at a fault zone.

The client's geotechnical specification hadn't anticipated extreme anisotropic pressure on the lining, said Seli, a member of the JV contractor undertaking the bore as part of a bigger tunnelling package.

The last 30 rings were deformed with the four nearest to the shield suffering severe damage. The ground was stabilised, the damaged rings removed and replaced with special steel rings, and the TBM recovered and repaired. Polymer resin was injected into the last 50m of tunnel. The steel rings were used until beyond the fault zone. A total of 34 rings have been installed. In January, once past the fault zone, lining was changed back to segmental concrete.

The JV contractor includes Pizzarotti, Bilfinger Berger, Alpine Mayreder, Beton –und Monierbau, Jaeger, Seli, Collini Impresa Costruzioni, and Societa Italiana per Condotte d'Acqua.

The client, Brenner Basis Tunnel SE, plans a total of four contracts to construct the exploratory tunnel as a single tube along the full length of the route. The final two packages will be in the middle of the route where overburden can be up to 1,600m and the area is a tectonic region.

The exploratory tunnel will become the service tunnel for the rail link, which will also comprise two running tunnels of 9.6m excavated diameters.

Hottest temperature ever recorded

A new record for the highest temperature ever recorded was set in February in a tunnel 12ft below Long Island, New York.

Scientists at the Brookhaven National Laboratory created a temperature of 4 trillion degrees Celsius, which is hotter than the 15M degrees Celsius found in the centre of the sun.

The temperature was created by tiny explosions.

Scientists used a giant atom smasher to knock gold ions together to make the explosions that lasted only for milliseconds. Each explosion was smaller than an atom, too small to be destructive.

"It's a hotter temperature than anything we know about in the universe," Steven Vigdor, a member of the team that reported the new record, told a meeting of the American Physical Society.

The scientists are trying to recreate the first microsecond after the Big Bang when the temperature of the universe would have been a few trillion degrees.

London Transport releases videos

copyright of Transport for London, Collection of Londons Transport Museum

London Transport gave access to a selection of documentaries about public transport in the city in February. The eight documentaries, available for free online, tell the story of some of the key moments in London's transport history dating from 1910 to 1970.

One of the films included is Piccadilly Line Extension from 1932.

The other films are A Trip on the Met Railway from 1910, LGOC Route 107 from 1923, Our Canteens from 1951, The Elephant Will Never Forget from 1953, All That Mighty Heart from 1962, Automatic Fare Collection from 1969 and London on the Move from 1970.

A London Transport Museum spokesman told T&TI that, "When most people think of London Transport, they only think of busses and trains, but there's much more to it than that. These videos show some of the history of our city."

He added that the eight videos available are a trial to see if there's an interest. If there is, then more will be made available in the future.

The films can be seen by visiting London Transport Museum's website.

Investigation reveals discrepancies

Investigations in to last year's Cologne city archive collapse have revealed evidence of discrepancies in vital documents and claims of workers selling construction materials for scrap.

In March 2009 two people died when the city's six storey archive building collapsed, taking with it two residential buildings on either side. It was located near a deep cut and cover box excavation below a road that was to form part of the city's metro system.

The job was being undertaken by Bilfinger Berger, Weiss and Frey and Zublin in a joint venture.

Martin Büllesbach, head of communications at Bilfinger Berger, and speaking on behalf of the JV told T&TI: "Investigations are ongoing regarding the collapse and at the moment the bigger issue is an ongoing second investigation in to discrepancies found within crucial documents."

Between 20 and 30 records are believed to have been forged. These were discovered during investigations in to the collapse of the archive, and relate to the diaphragm walls of the Waidmarkt cavern. "The protocols relate to the size, depth and width of the holes that form the diaphragm walls which create a cavern that will form an underground station," said Büllesbach.

The documents suggested that necessary shear dowels had failed to be installed at joints of the tunnel's diaphragm wall reinforcements, leading to claims of theft from site.

Büllesbach said, "It is sad we have this accusation, it seems to be correct." Bilfinger Berger checked two separate areas and discovered only two shear dowels where there should have been ten. However, even if all the shear dowels were missing that would only equate to 1% of the total steel amount used on site.

He added, "To sell left over material from site is acceptable, but you can't sell things that are supposed to be in there!"

This sentiment is echoed throughout the company. In a personal letter to Cologne's mayor Jürgen Roters, the Chairman of the Executive Board at Bilfinger Berger Herbert Bodner said, "For me, as an engineer, the failure to install shear dowels at the joints of the diaphragm wall reinforcements is inconceivable and something that I have never seen in all my years of professional experience."

However, it is the falsification of construction data that the JV are most concerned by.

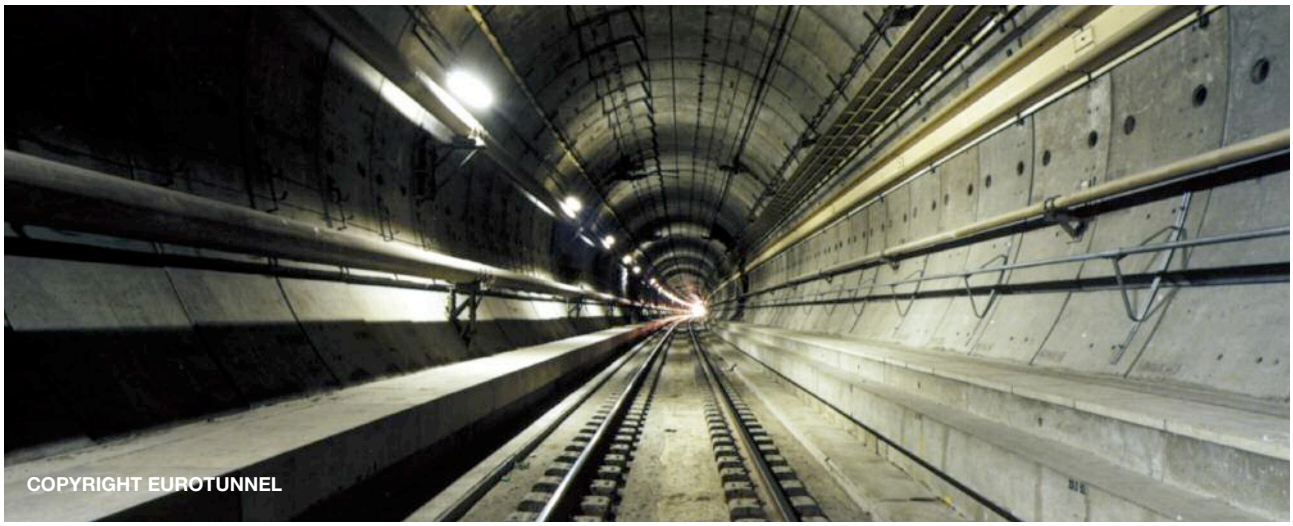
"This is the big issue and it is unacceptable. Why are there protocols missing, or looking alike? Was it manipulation or a mistake? It is not clear," said Büllesbach.

All members of the JV are 100% behind the investigation. The tunnel's owner, Kölner Verkehrs-Betriebe, was unavailable for comment.

It is unclear when the job will be completed, or when work will recommence. Büllesbach told T&TI, "Number one priority right now is to secure the archive materials. This might take another few months. Even if this is solved by the end of the year and work can restart, plans will have to be drawn up again."

"We are not even able to open the Waidmarkt cavern due to things from the archive being in there. It's bad news for the people of Cologne."

Eurotunnel breakdowns lead to enquiry



Eurostar had no working plan to evacuate broken-down trains caused by the snow, independent experts claimed in February.

The study, which was ordered by the UK government after five trains broke down in the tunnel in December, concluded the high speed train operator must implement an "urgent review" of its evacuation plans and give staff on its trains the same stress management training given to airline cabin crews.

The review, when examining the technical causes of the breakdown, found that the trains were not properly prepared for severe winter weather. Some 40cm of snow fell around the Calais terminal.

According to the report, passengers endured overflowing toilets on trains, as well as cold and darkness for hours. The report said that Eurostar should have been better prepared to cope with the disruption.

The trains broke down on the night of 18th December, leaving thousands of passengers trapped in the tunnel for up to five hours. Eurostar then cancelled all trains for the next three days, disrupting the travel plans of up to 90,000 passengers. Eurostar blamed the breakdown on "fluffy snow" which got into the trains' engines.

The review panel was headed by former GNER East Coast Main Line rail boss Christopher Garnett, and French transport expert Claude Gressier.

In total the review made 21 recommendations concerning the reliability of Eurostar trains, evacuation and rescue procedures in place in the tunnel, and the way Eurostar manages disruption. It also demanded better crisis management between Eurostar and Eurotunnel, the tunnel's owner.

"If a train breaks down and passengers have to be rescued or evacuated, this must be done with greater speed and consideration and more comprehensive emergency plans should be put in place," wrote the two experts.

Orlovsky tunnel bidding

St. Petersburg's City Hall will reopen tender for the city's 47.7bn ruble (US$1.6bn) Orlovsky tunnel in February.

The tender commission will start examining bids for the construction and operation of the tunnel, with officials planning to select a private partner for the project in April.

The 1km tunnel will run underneath the river Neva between the Smolnaya and Sverdlovskaya embankments. The city budget, the federal investment fund and a private partner will finance it equally.

It is designed to ease current congestion of the transport network in the city centre; to provide a permanent transport link between the right and left bank districts of the city; and to take away the exhausted capacity of the current Neva bridges. The overall capacity of the tunnel will be 60,000 vehicles a day.

The original estimate of 26.4bn rubles (US$865M) in 2007 almost doubled last April to today's expected cost.

A preliminary screening for applicants was held at the end of 2007. Nevsky Concessionary Company (a daughter company of Vinci;) Nevsky Tunnel (a consortium of Strabag, Zublin, Egis and Basic Element;) Bouyguesproject Operating (a daughter company of Bouygues;) and Neva Traverse (a consortium of Hochtief and Boskalis) passed the first round.

Government officials planned to select a partner by July 2008 and expected to open the tunnel by 2013, but the selection process was hampered by delays. The federal government officially put back the tunnel's completion deadline last April to 2015 after St. Petersburg's deputy governor Yury Molchanov announced that the city budget and federal investment fund would not be able to finance the tunnel's construction until 2011 at the earliest.

St. Petersburg investment and strategic projects committee chairman Alexei Chickanov said in a statement that there will be several new bids and that the city will find the necessary funds for the tunnel despite the economic crisis.

Lane Cove Tunnel update

Sydney's Lane Cove Tunnel backers are seeking some AU$600M (US$521.2M) for the asset which was placed in administration in January.

Receiver KordaMentha is expected this month to allow potential bidders to review financial data, with Leighton Holdings among the first to have access.

KordaMentha expected several parties to bid for the tunnel as equity and debt markets improve and with traffic through the tunnel growing.

The privately financed twin-tube tunnel was owned and operated by Connector Motorways.

Booth completes refurb contract

Booth Industries completed work in February on the £250,000 (US$393,000) contract to supply bespoke and commercial steel doors for the M25 Bell Common Tunnel.

The contract formed part of the £90.4M (US$142.1M) scheme by the Highways Agency to refurbish the tunnel. The project involves replacing mechanical and electrical equipment installed in the 1980s when the tunnel was constructed.

Booth were brought in by the main contractor Costain to supply specially designed steel fire doors fitted to the central dividing wall of the east and west bound bores of the tunnel, providing fire escapes.

Aker Wirth to deliver TBM to Switzerland

Aker Wirth was commissioned in February to construct and deliver a gripper TBM by ARGE Zugangsstollen Limmern (AZL).

The €20M (US$27.5M) TBM will be used in the expansion of the Linth-Limmern hydropower plant in Switzerland, constructing a headrace galley approximately 4km from the access gallery to the new machine cavern.

AZL is a joint venture consisting of Rothpletz, Lienhard & Cie; Baresel; Wayss & Freytag; G Lazzarini & Co; Andrea Pitsch; and Ragotti & Webber Bau.

The borehole has a diameter of 8.03m and rises from 800m to approximately 1800m above sea level with a constant gradient of 24 per cent. The project will be the largest inclined shaft completed by TBM, with previous diameters of up to 6m.

The TBM will be supplied fitted with a backup system constructed by Rowa Tunnelling Logistics where materials can be conveyed between the machine and portal, in addition to the securing and lining of the tunnel walls drilled.

The TBM will be constructed at the Erkelenz plant. It will be subject to an in-plant test run before being transported and assembled at the site.

Work on the tunnel will start at the end of this year.

Final tunnel package call at Crossrail

Crossrail has called for contractors to submit expressions of interest (EoI) for the third, and final, of the main tunnelling packages on the project. Other recent developments include award of the first enabling works contracts with a combined value of £27M (US$42.5M).

The contract package (C310) includes construction of 6.2m twin tubes to run below the river Thames between portals at Plumstead and North Woolwich. The section of the project in southeast London is approximately 2.6km long, and deadline for EoI submissions is 24 March.

The other two larger tunnelling packages are C300 and C305 for the twin tunnels in central London. Five Joint Ventures were shortlisted to bid for the works, which make up approximately 85 per cent of the running tunnel construction. They were Balfour Beatty, Morgan Est, Vinci and Beton- und Monierbau; BAM Nuttall, Ferrovial Agroman and Keir; Costain, Skanska and Bilfinger Berger; Dragados and John Sisk; and Laing O'Rourke and Bouygues.

Separately, Crossrail has awarded the first six enabling works contracts including the package (C330) to Costain Skanska JV for preparation of Royal Oak Portal from where the first pair of TBMs will be launched in late 2011.

Other recent milestones in construction activities include the start of dewatering for construction of the major box station at Canary Wharf.

German Railway invites tenders

The German Railway Administration will issue an invitation to tender for the upgrading of tunnel lining in two of their rail tunnels.

The works, in the 332m long Langenauer tunnel and the 319m Hollrichter tunnel, will also include track laying.

The tunnels, located on the Wetzlar-Koblenz railway line, will remain operational during works.

The procurement will start in April with works expected to begin in June. Both tunnels are scheduled to be operational on two tracks by 2012.

Herrenknecht in new TBM joint venture

Herrenknecht entered into a Joint Venture last month with Abu Dhabi-based Aabar Investments (Aabar) to engineer, design and build TBMs and related equipment.

The deal will see Aabar own 51 per cent of the UAE based company.

Company operations will include the assembly and manufacture of tunnelling technology and vertical drilling rigs to serve customers in the Middle East and North Africa.

The share capital of the JV is AED 25M (US$6.8M) of which Aabar's share is AED 12.75M (US$3.5M).

AECOM gets LRT contract

AECOM Technology Corporation has been awarded a €14.8M (US$20M) contract to provide project management services for the extension of Light Rail Transit (LRT) system in Edmonton, Canada.

The company will provide services for Phase 1 of the 3.2km-long extension, which will continue on from the existing underground LRT: firstly as a roughly 900m long tunnel and then as a 2.3km surface line.

The construction value of the project is €520M (US$708M) which will see the extension run from downtown Edmonton to the Northern Alberta Institute of Technology.

New Jersey transit awards

NJ Transit's US$8.7BN Mass Transit Tunnel, the rail project designed to double commuter capacity between New York and New Jersey, has got on track with the approval of the first two of three tunnelling contracts.

NJ Transit's board of directors awarded a US$583M contract for the mile-long Manhattan section of tunnelling to a joint venture comprising Barnard of New Jersey and Judlau Contracting of College Point, NY.

The Manhattan tunnel design-build contract forms part of a project to build two new, single-track commuter rail tunnels under the Hudson River, which will double the capacity of the existing 100-year-old, two-track tunnel that is currently operating at full capacity.

This will involve the construction of a 49m-diameter shaft, mixed-face starter tunnel breakouts from the shaft, four TBM-bored tunnels stretching 36m below surface through hard rock and three cross-passages.

In its entirety, the project is the largest public transport project in the US to date.

Brisbane's Northern Link bids

Transcity, Northern Direct and a joint venture between Leighton, Baulderstone and Razel, are the three companies that have chosen to bid for Brisbane's €1.35bn (US$1.84bn) Northern Link twin-tube road tunnel.

The project aims to facilitate better traffic flow in the busy city, while the tunnel is expected to bring other benefits, including €6.7bn (US$9.2bn) worth of economic benefits, improved access and road capacity, plus an additional 5,000 jobs in the city.

Previously, the project began as a private-public partnership; however the local government is now set to fund the project by servicing tunnel tolls.

The overall length of the tunnel is 7km, including the TBM-bored 4.6km-long eastbound tube and 4.9km westbound tune. The Northern Link will be bored through competent rock.

The project is scheduled for completion in 2016.

Annweiler tunnels contract

German company Dürr at Weinstadt-Endersbach, secured a €10.8M (US$13.5M) contract to re-equip the four B10 Annweiler tunnels in the Rhineland, Kostenfels (304 m), Staufer (1,038m), Lowenherz (900m) and Barbarossa (616 m), with renewal of electrotechnical equipment, installation of traffic management system and rescue niches.

The company has been awarded a second contract, worth €18.5M (US$25M) to renovate the Langenauer (332m) and Hollricher (319 m) tunnels.

It plans to include new inner concrete shells, to be placed concurrently with operation of the tunnels.

Rome Metro

Italian company Seli signed a contract with JV Salini Costruttori, Tecnimont and Icop for excavation of a new section between Conca d'Oro and Jonio metro stations in Rome.

This includes excavation of a 950m-long tunnel, crossing of the 150m-long Jonio station, and supply and placement of 400mm-thick precast concrete segments.

The Herrenknecht EPB TBM, which has a diameter of 9.79m and a total length of 80m, will be driven from the Conca D'Oro station box.

The tunnel will be internally lined with precast concrete segments, 400mm-thick and 1.4m long, in a 7+1 configuration. It will have an internal diameter of 8.65m and an external diameter of 9.45m. Excavation will begin next month.

World Trade Centre Transportation Hub

The Port Authority has awarded a US$542M contract to build a new path station as part of the World Trade Centre Transportation Hub.

The contract was awarded to the JV of Skanska USA Civil Northeast Inc, Granite Construction Northeast, and Skanska USA.

Work for the project includes construction of four railway platforms and the installation of heating, ventilation and air-conditioning systems; plumbing work, fire protection, architectural design, and handicapped accessibility measures to serve around 200,000 daily commuters.

The new platforms will be on the same spot and replace the temporary platforms built in 2003. Work is set to commence in two months time.

In addition, there will be changes to toll booths at the authority's bridge and tunnel crossing after the board approved the purchase of a new toll collection system, to replace 12 year-old equipment. The board allocated US$175M for a system that will have the capability to accommodate cashless tolling in the future.

The board awarded the first contract of US$10.5 million to PBS&J Architecture and Engineering for management services related to the deployment of the new toll collection system. Installation of the new system will begin in late 2012 and be completed by the end of 2014.

Irvington Tunnel bids invited

The San Francisco Public Utilities Commission invited bids for the New Irvington Tunnel Project.

Bids will be opened on 11 March, with a contract award scheduled for April / May 2010.

Construction is expected to begin in May / June with final completion by May 2014.

The tunnel will be specified for excavation using conventional mining methods, including road headers and controlled detonations. The finished tunnel will be horseshoe shaped and have an internal diameter of 8.5-10.5ft (US$2.6-3.2m). The estimated construction cost is US$230M to US$260M.

The New Irvington Tunnel is part of the San Francisco Public Utilities Commission's US$4.6BN water system Improvement Program (WSIP) to repair, replace and seismically upgrade the water system's ageing pipelines, reservoirs and dams.

Boring through Future

Chile - Los Bronces Tunnel

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The Sandvik DTi tunneling jumbos are designed with user comfort and successful operations in mind. Together with the iSURE tunnel management program, their intelligent but easy-to-use operation system and advanced features offer an unbeatably accurate drilling result. Whenever a challenging tunneling job is at hand, turn to the Sandvik DTi jumbos. They guarantee that there will be no fuss. Just drilling. With precise results. And happy operators.

SANDVIK

Comment

Buried Legacy

If Benjamin Franklin had been a tunnel engineer he would have said: "there is nothing certain but repair and maintenance" - not death and taxes!

Maintenance and repair are often regarded as the 'Cinderella' of Tunnel Infrastructure.

A good deal of existing essential underground infrastructure is operationally vital and without which the public would quickly learn just how vital it was. Our vulnerable aging underground infrastructure ranges from utilities to public transport.

A recent Construction Industry Research and Information Association (CIRIA) publication, entitled Tunnels: Inspection, Assessment and Maintenance, contributes to the need to raise the issues confronting owners of aging infrastructure, not just in the UK, which provides the data and case studies for the book, but also globally. Everything we build underground now will be a legacy needing future care and attention. Not only do we need to ensure that our future underground infrastructure is durable, but we have to deal with the legacy of infrastructure built long ago. Indeed most of UK's existing underground infrastructure is technically passed its intended design life including that belonging to London Underground and Thames Water. This would apply equally to most European towns and cities, the eastern seaboard cities of America and many other established global metropolises.

CIRIA to its credit has recognised the issues and provided a practical guide for owners, designers and contractors for a range of tunnel types, construction and uses.

The publication focuses predominantly on brickwork tunnels, cast iron and steel and precast concrete linings, and masonry linings. The contents will be essential reading for those involved in maintaining the aging underground assets of rail, metro, water, sewerage and utility companies.

Dealing with the built underground infrastructure is like dealing with the human body. A bit of care and attention on a regular basis helps to mitigate the aging effect along with the occasional superficial or invasive surgery!

In parallel, UK Institution of Civil Engineers published a book titled Asset Management –Whole Life Management of Physical Assets. Edited by Chris Lloyd the book takes a wider view of the way society, decision makers and industry currently deals with the complete management of physical assets. The book is a series of essays ranging from culture, systems and analysis of asset management.

Asset management has traditionally been a technically focussed discipline and generally reactive and this book suggests it is time for an overall approach taking into account organisational and strategy components; a government and regulatory components and of course the technical component, i.e. a clear strategy linking government policy with physical asset options and investment requirements to make infrastructure more resilient.

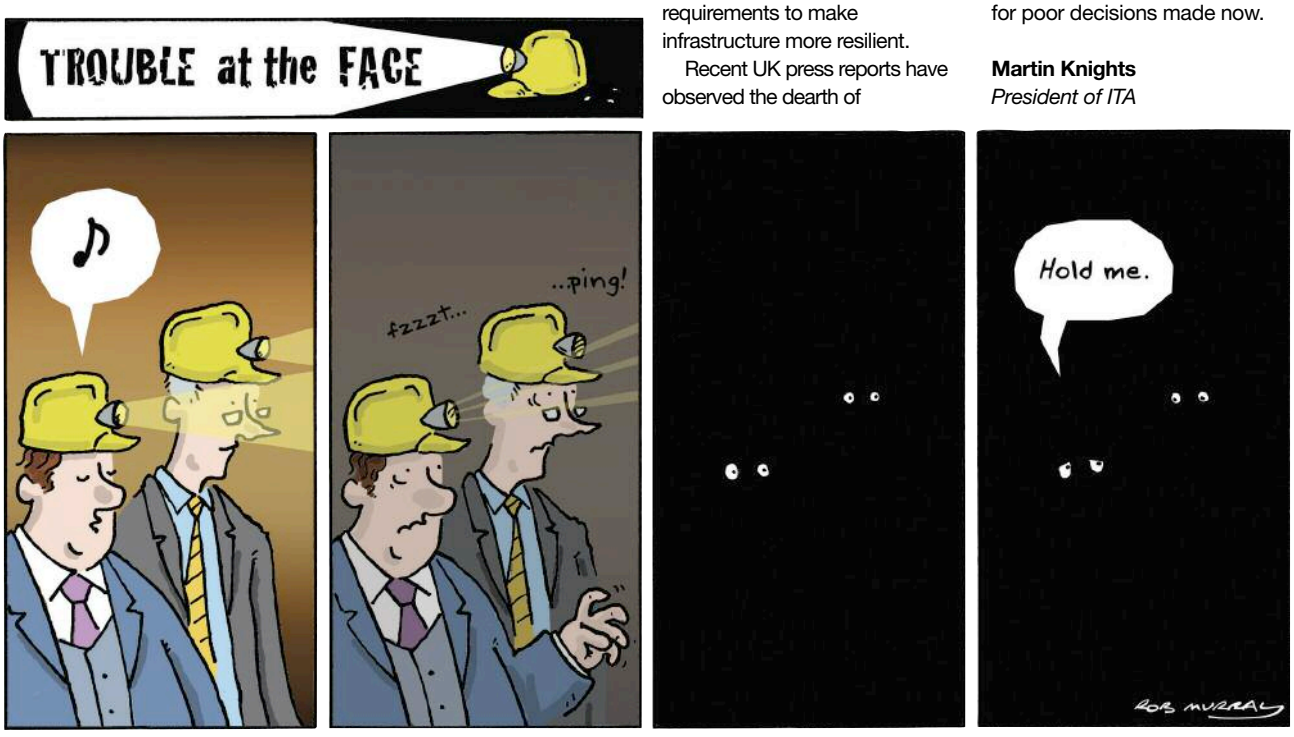
Recent UK press reports have observed the dearth of engineering or science (or even industry) background of politicians whose decision making on infrastructure sometimes shows expediency and lack of systematic assessment when faced with global issues such a global warming, climate change, security and strategic risks, scarcity of resource etc. - all issue close to ITA`s and ICE's heart.

Perhaps asset management's time has come?

If the two publications can demonstrate the need to take repair and maintenance from the reactive engineering level to the front end strategic level then engineers can enter the mainstream corporate and government decision making when considering key infrastructure solutions that are critical for society to function.

We as a profession must influence the long-term interests of society and refute short-term efficiency targets that drive current government decision-making. This applies to underground infrastructure that we are currently planning and building otherwise we will leave future generations to pay the price and suffer the disruption for poor decisions made now.

Martin Knights
President of ITA



Bauma 2010

Chairman of The German Engineering Federation (VDMA) Construction Equipment and Building Material Machinery Association and chairman of Bauma Advisory Board Christof Kemmann looks at how the current economic climate will impact on what can be expected from Bauma 2010

In the run up to previous Baumas, we have, at this stage, always been able to name records - such as full order books, booming markets and growing demands. Unfortunately, since summer 2008, the situation has drastically changed.

The drop in demand which occured so suddenly and nearly all over the world, is an enormous challenge for all manufacturers. Manufacturers of construction equipment are used to seeing fluctuations happening and therefore know how to handle them. However, this time, its scale as well as its speed are unique.

Measures to reduce cost quickly are therefore called for and many a company has already taken some. In this context, it is very good news that the majority of our members, many of which are small and medium enterprises, are striving to keep their permanent staff. Simultaneously, the time after the crisis needs to be taken into account. Unfortunately, Bauma 2010 is likely to be affected by all of this. It will be very interesting to find out which answers the manufactures have come up with. I am expecting to see a high number of innovations. The large amount of applications for the Bauma Innovation Award 2010, which we have been happy to find, already gave us some idea.

Bauma is a positive sign - despite all trends, it is fully booked. This fair is such an important indicator of the mood and situation our industry finds itself in. We hope that a strong Bauma will back up the change of atmosphere which is so important for our industry. However, we must not expect miracles in 2010.

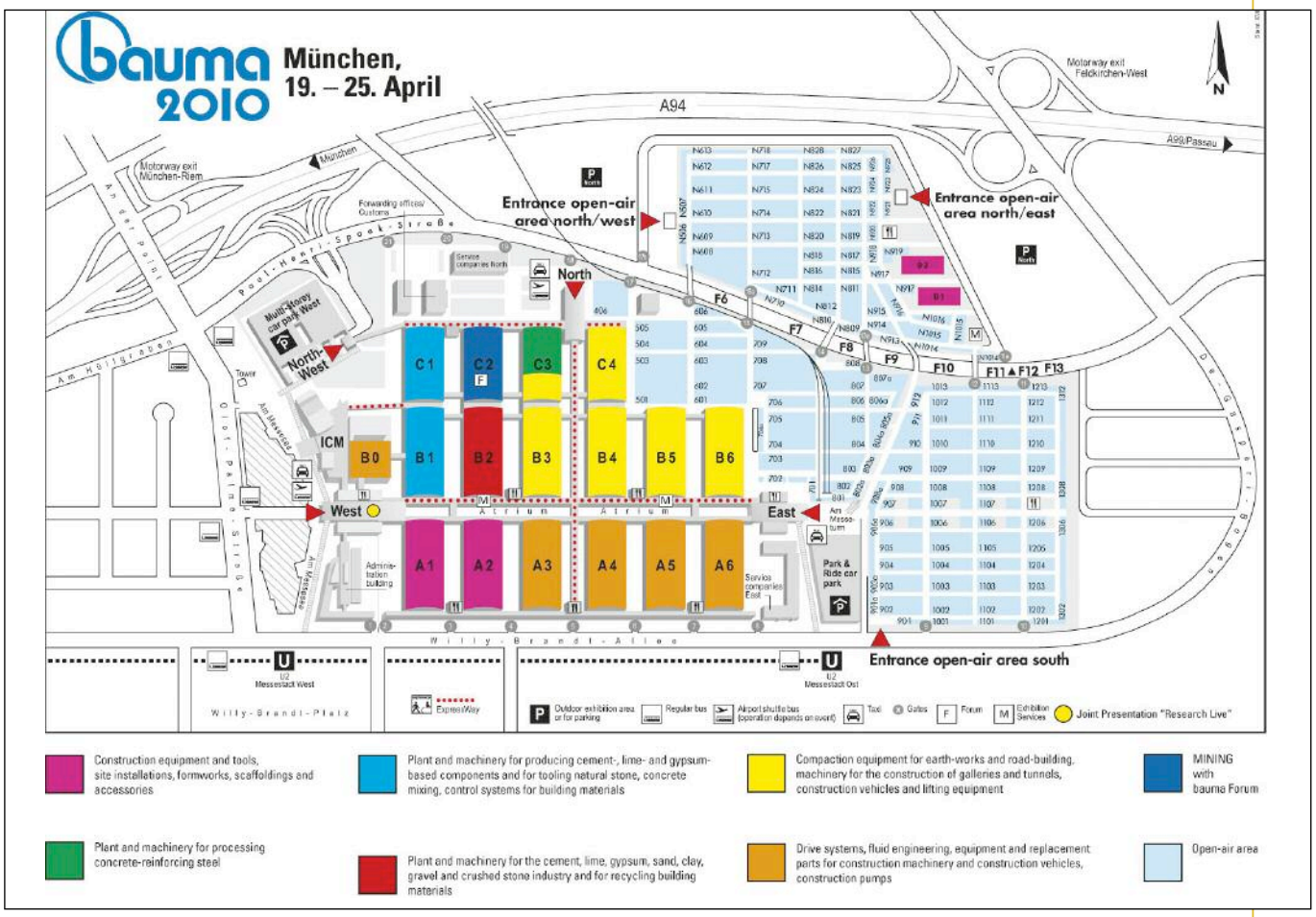
Drop in sales

At this very early point in time, we are able to be slightly optimistic when looking at the amount of incoming orders. During 2009, so it seems, the companies belonging to the construction equipment and building material machinery industry have bottomed out. Throughout that entire year, their amount of incoming orders and industry-wide sales dropped by about 50 per cent on average; making the current volume equal to our 2005 figures. The fact that numbers of orders in the field of construction equipment and machinery have decreased in 2009 will only become visible in 2010, as lead times have become significantly longer also. Many a manufacturer will have to face a drop in sales and capacity utilisation this year.

2009 mining machinery records

For the mining machinery industry, 2009 was a record year in terms of sales. However, the number of incoming orders fell immensely. Therefore, particularly in 2010, problems with regard to capacity utilisation are to be expected. However, the industry hopes to maintain its overall turnover achieved in 2009 also in the running year. There are signs that at least some of the orders that were cancelled last year because of the economic crisis will be filled this year.

There is no reason to be euphoric whatsoever and companies are preparing themselves for a lean time.



Mood brightening up

However, the current business climate index as well as the business barometer provided by our European umbrella organization CECE, are reasons for hope. The majority of companies expect to see their business activities go up again. This view is supported by the fact that we were able to see a slightly rising number of incoming orders at the end of 2009. Also the bottleneck in stock, which particularly dealers and equipment rental companies experienced, is nearly totally overcome. We also see a slight upturn again in the building material machinery business. Projects, which had been put on hold, are being put forward again with demands go up. The enormous challenge here: New projects within the engineering industry do not necessarily translate into a higher workload also.

High growth rates a thing of the past

It is obvious, however, that growth rates, similar to the ones we saw between 2003 and 2008, are currently and for the near future not to be expected, as:

- the growth rate during the boom phase had been higher than the real demand,
- the growth rates currently forecasted for the European construction industry are on a low. A lasting growth is not expected before 2011,
- the amount of "young" second-hand machinery available worldwide is still very high and a large amount of machinery currently in use is relatively new,
- financial support by banks, however urgently required, is still rather difficult to achieve.

Long-term forecast positive

In 2010, the course is to be set for the time after the crisis. The long term forecasts for the construction, building material, mining as well as the machinery industry worldwide are positive. This is thanks to rapidly growing markets in Asia and other regions, such as Brazil, for instance.

India Partner Country of Bauma 2010

This can be seen at Bauma also. We learned that bauma 2010 is going to be more international than ever. More and more exhibitors come from exactly those afore-named growing markets. India is the partner country of Bauma 2010. India was able to get out of the economic crisis very quickly and with hardly any damage. The Indian construction and mining industry expect growth rates of 11 and 12 per cent, respectively, per year on average until 2015. With this, both sectors are above the expected GDP growth rate. Within the next three years, the demand of machinery and equipment will be increasing by 20 per cent.

We would also like to invite exhibitors and visitors to take a look at the events focussing on India which accompany this year's Bauma. We have prepared, among other things, a seminar on infrastructure and construction issues as well as a "Spotlight on India" to be held at the bauma forum in hall C2.

Additionally, we offer "country spotlights" on Russia, Asia and Latin America from the 2nd to the 4th day of Bauma. All of these take place at the Bauma forum. They will follow the same concept but are currently being drawn up in detail. If you would like to find out more about them prior to attending Bauma, please contact the VDMA directly. T&T

Opening hours

19- 25 April 2010

Mon - Fri:	9.30am - 6.30pm
Sat:	8.30am - 6.30pm
Sun:	9.30am - 4.30pm

What to spot at Bauma

Bauma is the world's largest trade fair for the construction industry so finding your way among the more than 500 000 m^2 of plant and machinery requires careful planning. Every three years the trade fair, which was launched more than 50 years ago, showcases the full range of construction machinery, construction equipment, vehicles and tunnelling and mining machines.

Some 3000 exhibitors will be displaying state-of-the-art technology and expertise to the nearly half million visitors to the show. Exhibitors are expected to target the aftermarket business at the event alongside the launch of many new products. Many companies will be promoting the industry to the wider construction market in an effort to fill a skills gap.

Hammering the point

Rock drilling tools manufacture Rockmore International's new ROK Series DTH Hammer product line, the ROK 875, is being launched at the show. This new 8in (203mm) diameter class hammer is designed to increase drilling efficiency in tunnelling, mining, blast hole, construction, and quarry applications. The ROK 875 features a new design which reduces the number of hammer components. The integrated top sub, for instance, combines multiple internal parts into one component. That reduces the amount of component wear points, reduces cost, and simplifies service.

The streamlined design also takes full advantage of Rockmore's unique SonicFlow technology, which optimizes airflow by simplifying the air path. "Our R & D staff found that every time the airflow changes direction, energy is lost through turbulence," noted Pejman Eghdami, executive vice president of Rockmore International. "With fewer obstructions, more energy is delivered to the piston while minimising backflow interference. We've also added smooth radius ports in the airflow chambers, which minimise energy losses even further. That means faster penetration rates and greater overall efficiency."

Rockmore International Stand C2 – 317

A fresh airing

Atlas Copco will launch a new carrier-integrated breaker ventilation system for tunnelling applications. The ventilation system delivers additional air to minimise the risk of extensive wear on hydraulic breakers. Hydraulic breakers are suitable for tunnel heading, scaling, extension and demolition work. When working underground, abrasive dust in the air can enter the percussion chamber, the oil circuit between the attachment and the carrier can become contaminated, and rust can form on the piston from water sprinkling on the breaker. All these factors can cause considerable wear on the breaker.

To avoid these problems, an additional air source can be supplied by means of carrier-integrated breaker ventilation. The system is easy to install by a simple hydraulic connection to the breaker installation of the carrier, while the electronic system of the carrier is not touched. The new breaker ventilation requires no separate ground space, and no extra person is needed for the air hose. It is synchronized with the hydraulic breaker and operates without emissions.

The breaker ventilation system is available for Atlas Copco breakers of the 1000 – 4200-kg class.

Atlas Copco Stand F10 – 1008

Tunneling tales

Most people in the industry agree that the majority of tunneling projects are beyond boring – they usually face unforeseen challenges in one way or another. TBM manufacturer Robbins has worked with contractors to overcome challenges using both trusted and innovative approaches. Robbins presentations at Bauma will be focused on real tunnelling stories. Topics will include ground support, high cover tunnelling, and fast machine production. The booth will also feature written materials about difficult projects, and will be staffed by employees from around the world.

Over the years, Robbins has honed its successful tunnelling support for the real life conditions encountered in the field, whether that means fractured rock, mixed ground with boulders, or urban tunnels close to existing infrastructure.

In Guangzhou, China, two 6.3 m EPB TBMs excavated weathered granite, sand, and silt using adaptable additive systems and real time monitoring to reduce surface disturbances. The machines broke through with multiple project records including a best month of 377 m.

Robbins Stand C2 - 401

In the mix

Lintec are the only manufacturer in the world who produce mixing plants in 100 per cent ISO sea containers. They are bringing four new containerised mixing plants to Bauma, two that deal with concrete and two that deal with asphalt. The plants are designed in such a way that the containers are a combination of easy transport units and the 'in-housing' of a plant.

Lintec Stand F12 – 1211/1

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Crane sailing

Manitowoc will present the new Grove GMK6300L, which offers some of the strongest lifting abilities of any 6-axle, all-terrain crane and offers more power when lifting at tall heights. It has been designed to offer unprecedented ease in applications such as placing placing machinery and items in tunnel shafts.

Manitowoc Stand F10 – 1002/6

Keep on rolling

The Rumelca Group is a leading global components manufacturer producing a wide range of rollers/idlers, motorized pulleys, pulleys and other conveyors equipment such as belt cleaners and covers. Its products are designed for bulk handling conveyors applications ranging from light duty, medium and severe heavy duty applications. They deal with the global mining industry as well as power stations, ports, quarries and steel plants. At Bauma 2010 Rulmeca will display the complete range of Idlers/rollers and Motorized Pulleys: special focus will be given to the widened range of thermoplastic rollers developed based on market demands for stronger but lighter rollers with a lower resistance of rotation, lower noise levels and maximum resistance to abrasive and corrosive materials.

Rulmeca Group Stand B2 – 317

Make a break

Doosan will be launching several new products including crawler excavators, a large wheeled-loader and a range of hydraulic breakers at the expo. The new crawler excavators include the DX700LC, the largest in the Doosan range which is designed and built to meet the needs of heavy duty mining and quarrying applications as well as major infrastructure construction projects. Also on show will be the new DX380LC crawler excavator which is suitable for jobs ranging from heavy construction and excavation to development of construction sites, construction and renovation of highways and other large works of civil engineering as well as mining and quarrying.

The DX235LCR crawler excavator is designed to meet the continually growing demand for reduced radius crawler excavators for work near buildings and in confined areas. Also on show will be the DL420 large wheeled-loader which has a bucket capacity of 4.0 m^3 and is intended to meet a wide range of material-handling needs from loading and transporting granular material, to industrial, mining and quarrying applications.

Doosan are also bringing the DXB170 and DXB260 models from the new DXB hydraulic breakers range. These are intended for work in demolition, highway and road projects, mining, and in general construction.

Doosan
Stand F6 – 601/602/3

Nothing boring about this

For the first time, German tunnelling heavyweight Herrenknecht is bringing its entire portfolio to Bauma 2010. The company delivers state-of-the-art tunnel boring machines for all ground conditions and in all diameters – 0.10 to 19 metres. The Herrenknecht Group includes subsidiaries and associated companies in related sectors in Germany and abroad, and creates project-specific equipment and service packages for our customers on demand. Areas of their expertise include separation plants, conveyor belt systems, navigation and guidance systems, lining segment moulds and complete lining segment factories. Additionally, it offers services in technical planning and monitoring of tunnelling machinery and individual solutions in personnel recruitment. The company also provides state-of-the-art deep drilling rigs to bore to a depth of 6000 metres and small drilling devices for use in shallow geothermal energy. Herrenknecht is hosting two stands this year, with the open-air stand focusing on horizontal and vertical drilling equipment especially for pipeline installation and exploration of shallow geothermal energy.

Herrenknecht; Herrenknecht Formwork Technology stand C3 - 315/512
Herrenknecht stand F7 – 703/12

Happier hammering

FRD brings the Xcentric Ripper to Bauma 2010, a new excavator attachment, which guarantees higher production, minimum maintenance cost and reduced vibration for excavator and operator as well as reduced noise levels. The attachment is developed with a patented reaction power accumulation technology, which makes it more productive then any hydraulic hammer available in the market across 85 per cent of job types.

It is available in a wide range of models, with 10 different sizes for excavators from 2 to 85 tonnes. The initial introduction at Bauma will be with three models: XR 6 G0 for 5~9 tonne excavators and backhoe loaders, XR 25 G0 for 19~25 tons crawler excavators and XR 35 G0 for 30~39-tonne excavators.

Furukawa Rock Drill Europe BV Stand F6 – 603/4

Streets ahead

Fayat will be bringing many examples of their road building equipment that relate to the areas of preparation of roadbeds; the production of all types of materials used in road building including gravel; cement mixture; cold-, warm- and hot-mix asphalt; paver finishers; compaction equipment for use with bituminous asphalts; and machinery dealing with the maintenance, milling and surfacing of carriageways; and new technologies. There is also an emphasis on recycling and an area dedicated to environmental equipment, with a particular emphasis on foundations kit.

Fayat **Stand F10 – 1009**

Breaking up

At Bauma 2010, Montabert will be launching the new Blue Line range of hydraulic breakers and a new range of crusher buckets for use on excavators from 8 to over 35 tonnes. The new breakers and crusher buckets are designed for applications in demolition, recycling, quarrying, construction and refurbishment. The range of Blue Line breakers, which complements the existing family of breakers from Montabert, is designed as an entry level range of quality breakers with a simple, cost-effective design offering high performance and efficiency, durability and easy serviceability.

The new crusher buckets easily mount on any make of excavator, requiring only one-way auxiliary hydraulics to operate. They can crush concrete, brick, blocks, asphalt, aggregate and many more materials on site and can easily be adjusted to produce different sizes of output materials, reducing hauling and tipping costs. They can turn useless debris into material that can be used on site, on other projects or sold to other contractors.

Montabert **Stand F4 – 406/3**

Robotic demolition

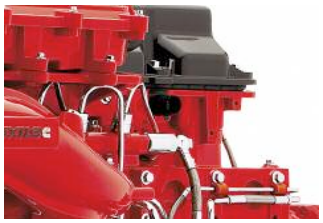
Finmac brings the Finmac F16 remote- controlled and electrical demolition robot to Bauma 2010. The machine is designed for safe and efficient demolition work in confined and hazardous work areas such as small tunnels. An electrical motor, resulting in zero emissions and no exhaust fumes, propels the machine and its attachments.

The F16 is exceptional in its separate upper and lower carriage design. The power cable is connected to the lower carriage, which enables a 360-deg continuous movement of the upper carriage. The low point of gravity results in excellent stability.

The computerised remote control uses a radio signal to control the robot at up to 300m. The operator works from a safe distance and is not exposed to dangerous debris or dust.

Finmac Demolition Oy **Stand A1 – 214.**

Clean power



Engine manufacturer Cummins will reveal four new engines at the show designed to meet the latest emissions regulations. This will mark the debut of Cummins next generation of 4-cylinder QSB3.3 and QSB4.5 engines for compact equipment, together with a first showing of the all-new QSX11.9 and QSX15 heavy-duty engines suitable for tunnelling machines. The four engines will be displayed at Bauma as complete air-intake to exhaust after treatment systems.

Cummins **Stand A4 - 319/410**

Driving range

Comer Industries extends its range of drive gears with rotating outer casing with the new PGRF25000 model. It has 250 kNm nominal torque at output and features the typical flange to be connected directly to the fixed support on one side, and the mobile flange, included in the rotating casing, to which a side of the drum is directly secured. The double mobile-flange rotation conical roller bearing acts as a winch support. A Duo-Cone front seal between the two flanges seals the reduction gear perfectly - even in the most difficult environmental conditions.

Comer Industries **Stand A4 – 113**

Diesel power

The Liebherr Group is displaying more than 60 exhibits from every area of its extensive construction machinery programme across a 13 500-m² outdoor site. One of the exhibits is the R 924 Compact Tunnel, a new special-purpose excavator for tunnelling work. It weighs 32.4 tonnes, is driven by a 130-kW (176-hp) Liebherr diesel engine and has a crowding length of up to 2.50 metres. The maximum tearout force is 135 kN and the maximum breakaway force is 85 kN. As well as operating with a spoil shovel, the R 924 Compact Tunnel can be equipped with a hammer of up to 1.7 tonnes or a rotary cutter in the up to 80-kW (108-hp) power-input category.

Thanks to its short-tail design, the R 924 Compact Tunnel is exceptionally compact and can be used with all frequently-used tunnel driving methods. It can excavate cross-passages after the tunnel driving machine has moved on; if blasting is used, it can produce the final profile, or it can excavate spoil from the tunnel face directly. In view of the limited working space available when tunnelling, the short-tail concept with its low rear-end slewing radius possesses significant advantages.

Liebherr Group **Stand F8 – 803-807**

Others to look out for

Company	Hall	Booth
Aker Solutions/Wirth	C3	209
BASF Construction Chemicals	C3	113
Bekaert	C1	102
Belloli	C2	512
Bohrtec	C3	315/512
Bohrtec Vertical	C3 F7	315/512 & 703/12
CBE Group	C3	306A
Ceresola	C2	504A
CIFA	F9	905/1
Ditch Witch	B3	301/402
Doka	F8	N811
DSI Dywidag-Systems	A2	321
Firep International	C3	513
GeneSys Elektronik	C3	315/512
Gia Industri	C2	413/510
Grindex	A6	115/224
Häny	C2	415
H+E Logistik	C3	315/512
Heinzmann	A5	326
International Tunnelling Services	C3	315/512
Lovat	C2	409
Maschinen und Stahlbau Dresden	C3	315/512
Minova International	C2	508
MTS Perforator	C3	207
NFM Technologies	C3	118
Normet	B3	225
Palmieri	C3	111
Perforator	C3	207
Putzmeister	B6	100/400
Rowa	C2	512
Sandvik	F6	605/1
Schauenburg Tunnel-Ventilation	C3	409
SELI	C3	110
Tacs	C2	416
TunnelTec	C3	521
Underground Technology Services	C3	315/512

www.bauma.de

First time

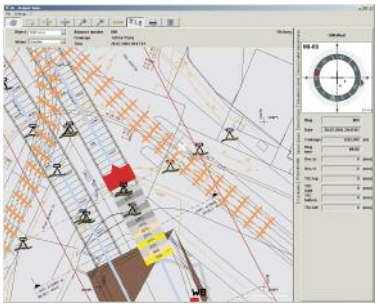
Bauma is becoming the world stage for more firms outside of Europe and 2010 will see Chinese construction equipment manufacturer LiuGong host its first ever press conference in Western Europe.

In 2009, LiuGong was one of just a few machinery companies experiencing growth. For the first time, the company will discuss earnings with the western press.

Executives from the company will discuss European and worldwide expansion plans and their business initiatives and products planned for 2010 will be previewed.

LiuGong Machinery Corporation
Stand F11 – 1111/4

Guidance for TBMs



In the 16 years since its inception VMT has become a leader for the supply of guidance systems for tunnel boring machines and for the supply of a full service for the metrology needs of modern tunnelling projects.

On display will be the new Tunnel and Underground Information Software Structure – TunIS. This is the platform on which all VMT guidance systems will now be based to enable the efficient inclusion of enhancements to satisfy the needs of an ever demanding tunnelling industry. The main products on show include the SLS-SL Guidance system for TBMs, the SLS-LT for pipejacked tunnels that are either curved or of extended distance, plus a comprehensive range of ancillary modules available for such tasks as data recording, automatic bentonite lubrication control, monitoring of selected pipe-joint gaps, working face distance measurement on open face shields and a video monitoring facility as well as remote data transfer.

VMT Stand C3 – 315/512 (as part of the Herrenknecht stand)

Moist see new technology

Imko will present brand new moisture sensors at Bauma 2010. Featuring novel SONO sensors, the new generation of moisture sensors were especially designed to meet the demands of the building industry but have multiple applications in other spheres. The sensors' decisive lead is generated by the deployment of state-of-the-art Trime radar technology.

Imko Stand B1 – 103/202

Monstrous creatures

Close to 60 Caterpillar machines will be on display, including the 301.6C mini hydraulic excavator and the 993K large wheel-loader. In particular, new and updated products will include the M325D L material handler with port handling attachment, AP555E asphalt paver, 434E and 432E backhoe loaders, 988H large wheel-loader, 50 DEM demolition excavator, TH417 telehandler, P200 series hydraulic concrete pulverisers and a new quarry body for the 770 rigid-frame off-highway truck. Many more new products will be on display for the first time in Europe.

The Caterpillar stand will feature a central area dedicated to practical, business driven innovations, technology and services designed to help customers' success, lessen environmental impact and work more safely. Most importantly, the area incorporates information on Tier 4/Stage 3B solutions, the D7E electric-drive, track-type tractor, as well as connected worksite technology with next generation Product Link and new integrated Cat Grade Control. The area also presents the Caterpillar EcoDrive concept, simulators for several Cat products and consultancy for a quarry site assessment.

Caterpillar Stand B6 – 102 – 402, Stand F7 – 703/1

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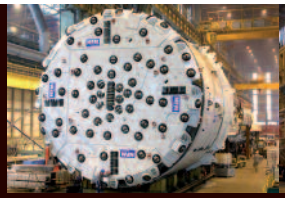
Christian Menanteau. Photo credits Benoit Brun, Dortmund, Lumiet.


Hard-rock TBM


Soft ground TBM


Dual mode TBM

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Slog on the Tyne

From box tunnels to immersed tubes, the second Tyne Tunnel is using a range of techniques for a new passage under the river, reports staff writer Emma Gritt.

Above: **Several excavation methods were used, including cut-and-cover with temporaray support struts removed as construction proceeded**

Newcastle's £260M (USD 202M) New Tyne Crossing project is one of the UK's largest infrastructure schemes. It involves the construction of a second vehicle tunnel to dual the existing A19 under the River Tyne. The new crossing is positioned to the east of the current Tyne Tunnel which dates from 1967. Upon completion, the total length of the new carriageway will be approximately 2.6 km with the tunnel itself making up 1.5 km of the total length.

At first glance the building of a new traffic tunnel might seem like a reasonably simple job, but in this case the River Tyne running over the middle of the route is throwing up a myriad of challenges for the concessionaire, Tyne Tunnel 2 (TT2).

Owners, the Tyne and Wear Integrated Transport Authority (TWITA), opted for a public private partnership structure to develop the scheme and appointed the TT2 consortium in 2007 for a 30-year concession period. TT2 is made up of Bouygues Travaux Publics, HSBC Infrastructure Fund II and Bank of Scotland Corporate. Bouygues Travaux Publics is the design-and-build contractor.

"It's a complex little job, it's not big in its footprint, but it is difficult, there are lots of different technologies involved," said Trevor Jackson, managing director of TT2.

To combat the precarious nature of the project, planning has been thorough. Although the tunnel is not particularly long, the challenges faced by Bouygues have resulted in splitting the works in to four distinct sections: the 318-m north approach; the 360-m river section; the 840-m south cut-and-cover section with the south junction, each of which arein progress simultaneously.

Due to the site's varied industrial history (in the past the area has homed breweries, dockyards and collieries), samples were tested for both contaminates and leachates. Stage one of the project comprised a geotechnical and contamination desk study of the proposed tunnel alignment and the immediate surrounding area. The aim of the desk study was to identify past and current potentially contaminative site usages and included a review of the available historical plans, geology, hydrogeology and hydrological information for the site.

Stage two was a preliminary ground investigation (PGI) along the line of the proposed tunnel to confirm the findings of the desk study and to obtain geotechnical and chemical information on the soils, rocks and groundwater. This information was used to assist in the compilation of the reference design for the proposed scheme. The PGI was carried out between May and July 2000 aimed at obtaining geotechnical and chemical information on the soils, rock and groundwater within the study corridor.

These investigations revealed that the geology far from constant. Daniel Clert, project manager, explained, "When you have a glacial location like we do here, under the water you find granular sandy conditions, then as you go up the banks you start finding different natures of soil, then clay and with that the rock at depth."

North of the river

The 318m-long north section relies mostly on cut-and-cover techniques. The geology of this section generally comprises the following strata: made ground, occasional instances of alluvium, glacial deposits (upper till and laminated clays, middle till, lower laminated clay, lower glacial till and basal sand and gravels) and Carboniferous Middle Coal Measures bedrock with interbedded mudstone, siltstone and sandstone and thin coal seams

There is considerable spatial variability in the made ground, alluvium and glacial deposits. Typically, towards the northern end of the section (towards the portal) the tunnels are mostly founded in the glacial deposits. As the alignment heads towards the north bank of the river it passes through lower glacial till and localised alluvial sands and gravels.

Following the construction of 600mm-thick diaphragm walls, approximately 170,000m^3 of soil was excavated from the area between. This was done in phases with temporary struts placed between the walls for support. The tunnel was then constructed in situ, using base and roof slabs to provide lateral support. The temporary support struts were removed as construction of the base and roof slabs proceeded. Following completion of the main tunnel structure, soil was used to backfill the space above the roof slabs to reinstate the necessary ground level above.

For a small section of the tunnel, this process was not suitable as the new tunnel passes over the existing one. For this area, a bottom down construction technique was chosen. This was to avoid any heave in the existing tunnel which would have been caused by removing the weight of ground material lying above it. In this area the roof slabs were constructed first, followed by excavation beneath the roof, and then construction *in situ*. All the while constant monitoring of the existing tunnel was taking place with highly sensitive movement sensors.

South of the river

The 840m-long south section is also being constructed using cut-and-cover methods, apart from two small sections of 32m and 40m which are being constructed using sprayed concrete lining in order to avoid major utility diversions. These two sections equate to approximately 4 per cent of the total land tunnel excavations. The general stratigraphy south of the river can be described as made ground (granular and cohesive) overlying either alluvium or sequences of glacial till and laminated clay which overlie bedrock of the Carboniferous Middle Coal Measures. The invert of the tunnel is within bedrock from the south transition structure for approximately 230m. The alignment rises up through lower glacial till and lower laminated clay sequences. The southern 600m or so of tunnel is within upper glacial till, laminated clays and made ground as the tunnel alignment runs near to the surface.

Sprayed concrete lining (SCL) sections were separated from the main cut-and-cover trench by 600mm-thick diaphragm walls that were constructed when the diaphragm walls for the cut-and-cover trench were built. These dividing walls are being broken through to enable excavations to take place for the SCL tunnels.

To the south of the tunnel interlocking secant piles have been used to reinforce the excavated space where the tunnel lies above the water table. The tunnel is on a gradual incline towards the surface from the river to the south exit of the tunnel. As the piles are not absolutely water-tight, the tunnel box must be constructed in its entirety within this section, whereas in other places, where the cut-and-cover technique is used, the diaphragm walls are used as the permanent walls for the tunnel structure.

At the south exit of the new tunnel, where both the new and the old tunnel run adjacent to one another, the tunnel is being constructed in alignment with the existing tunnel as a reinforced concrete box structure.

The needs of the formworks on both sides of the tunnel were specific and required bespoke solutions. “We needed to present the best system for each application. Each part of the job has its own little challenges,” says Paul Lawton of formwork provider RMD Kwikform. “With top down construction you couldn’t crane handle that formwork so you had to suspend it and that made it very easy to move. You needed be able to adjust the height of the supports of the north side, whilst on the south it was fixed almost all the way.”

On the north side of the tunnel, the base slab rises at a continuous 6 per cent incline whilst the height of the tunnel changes multiple times throughout its length, meaning that at points the soffit slopes by up to 12 per cent. RMD Kwikform engineering director, Ian Fryer summarises the situation: “The challenge was to deliver a whole-slab-area travelling formwork system with 2m height variation which could be operated without the site staff working at height. The traveller also needed to give the users the flexibility to snake the equipment up an incline of 6 per cent, travelling on rails whilst casting a slab that was up to 8.5m off the ground, at the bottom of a 25m deep excavation full of large ground shoring props.”

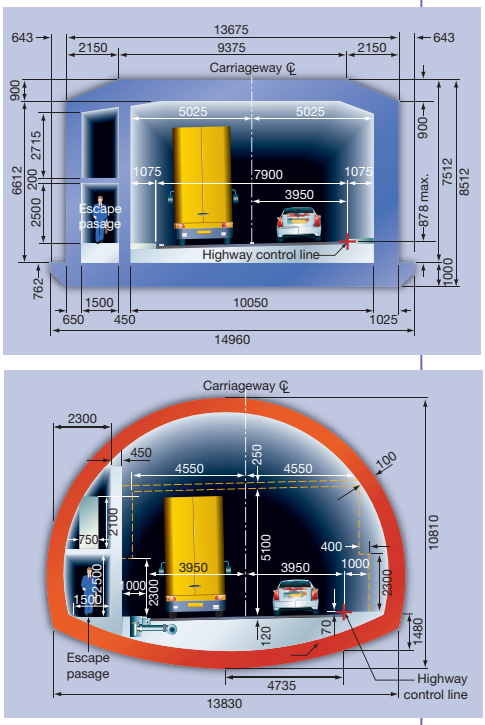
In transition

The north and south sections are joined to the central immersed tunnel section by two transition structures, which act like coffer dams, creating a dry space within which to prepare the connection between the two types of tunnel. The outer wall of the transition structures was removed once the connection point was constructed and the element was ready to be immersed and connected.

A rarely used approach was taken to break through the redundant outer wall. Clert explains: “We had to saw cut one side of the shaft in order to open the door for the tunnel element to get in. This required cutting through a 1m thick wall that is 25m below water and 25m height in sections. I don’t think this method has been undertaken very often on any projects in the world. For me it was one of the big worries of the job.”

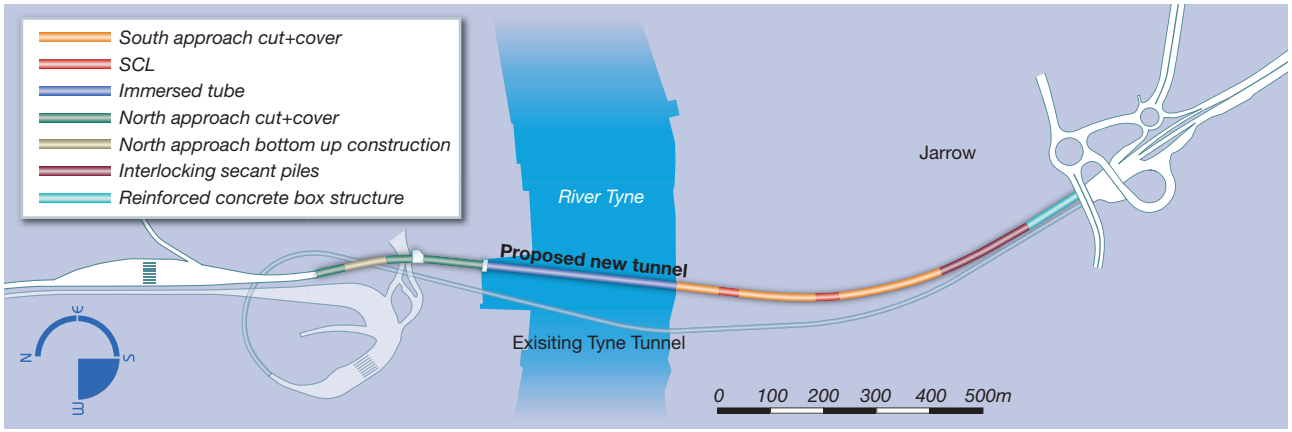
Understandably so because a delay with this activity would have delayed tunnel tube immersion and the whole project.

Cutting through the wall was done using a series of pulleys and ropes that effectively



Above: Design sections through the immersed tube (top) and SCL sections (lower) of the new Tyne Tunnel

Below: Map of the new tunnel route adjacent to the existing tunnel



Above left: Special RMD Kwikform formwork installed in cut-and-cover
Above right: Breaking through a wall in the SCL section
Left: Building the four immersed tube elements in Walker dry dock

cut through the concrete partition like a cheese wire. "We had to dispatch divers to install pulleys like that in the wall and start sawing the thing horizontally and vertically," says Clert. As a diver can only stay at the required depth of 25m for a minute or so a huge team was needed. At such depth, visibility was also severely restricted yet precision was key.

Crossing the river

During the construction of the transition structures, the Tyne was prepared for the arrival and placement of the concrete elements that make up the 360m-long immersed-tube tunnel section. November 2009 saw the arrival of the suction cutter barge 'Vesalius' which worked for six weeks preparing a trench for the elements to lie in. Around one million tonnes (520 000m^3) of dredged material from the river bed was pumped via a 2.6km-long pipeline directly to infill the Tyne Dock as part of existing redevelopment plans.

The four concrete pre-cast tunnel elements were cast by VolkerWessels UK at Walker dry dock, approximately 3km upstream of the tunnel site. "Initially the units were going to be built on the continent, but fortunately upon arrival in Newcastle we found that there was an unused dock that was suitable for fabrication of the units and we kick-started fabrication there soon after," says Clert.

Each tunnel element is approximately 90m long, 15m wide and 8.5m high. Overall, 14 400m^3 of concrete has been used to construct the river tunnel units. Each element is made up of four separate segments to enable a more robust final product to be built. Ballast tanks were placed within each tunnel element to enable final transportation. Once all tunnel elements were constructed the dry dock was flooded, ready for the tunnel elements to be floated out to the river, and downstream towards the tunnel site. The tunnel elements were berthed at Howdon Dock and fitted with immersion equipment, before being lowered into place.

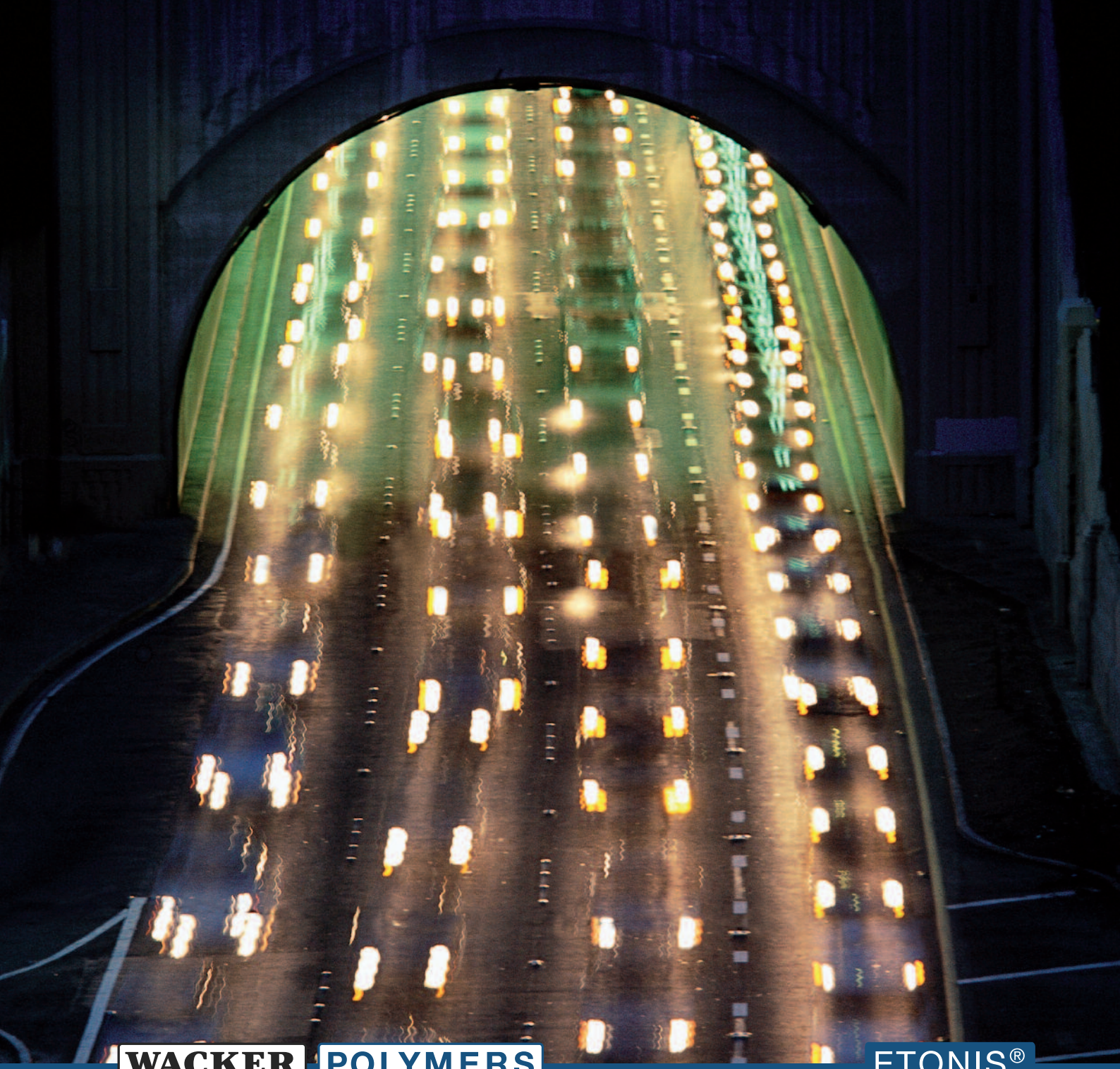
Each element contains five ballast tanks, two primary tanks located in the traffic corridor, and three smaller, secondary tanks in the pedestrian escape passage. The ballast tanks are a temporary construction within the permanent structure of the element. Each tank comprises a polythene membrane mounted on plywood and supported on timber joists. The timber joists are set on steel framework. The volume of the tanks varies according to the phase of activity. Each element is fitted with two tanks with a holding capacity of 1250m^3, one tank with a capacity of 212m^3, and two tanks that can hold 81m^3. The element can also hold up to 30m3 of trimmed concrete.

The units are sealed between one another with a Trelleborg Bakker Gina gasket which compresses under hydrostatic pressure. Once the units are connected in this way, the water-filled space between the bulk heads is pumped out. Each element has two flat steel plates attached to it at either end. At one end of each element the seal is attached to the steel plates so that when the elements are joined together the seal compresses against the steel flat plate on the other unit, and when they are compressed against each other the seal is created. The elements are compressed together with a force of 35t.

The initial primary seal is formed by the Gina membrane. Once in place, Trelleborg Bakker Omega seal is attached at a later date. The Omega seal will typically be placed some weeks after the gina seal, and becomes the primary seal. Should the Omega seal fail the Gina seal will remain as the secondary, permanent seal.

Each element was lowered into place, sequentially, once ready for immersion. Each element is being towed into the river channel by three tug boats and once secured in position the internal ballast tank filled to enable the element to sink. Using cables the element is carefully lowered into place on the dredged river bed. Once in place the tunnel elements closest to the river banks will be pulled towards the transition structures so that the connection between the two can be made.

Sand will be injected below each tunnel element, to secure it in place, using a sand flow technique. Once all tunnel elements are in place a closure joint will be constructed *in situ* to seal the elements together. Rock armouring will be placed above the tunnel, along its entire length, to protect the tunnel structure. At present three of the four elements have been laid in the Tyne. The new tunnel is due to be completed in February 2011 followed by refurbishment of the old tunnel for both to be operational in December 2011. T&T



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CREATING TOMORROW'S SOLUTIONS

Mexico's Urban Challenge

Giant Robbins EPB Assembled in Mexico City's Downtown Federal District is home to the first ever jobsite assembly of an EPB TBM. Robbins technical writer Desiree Willis reports

In the heart of Mexico City, between a new university and rows of apartment buildings, sits a cordoned off 250 m long section of Ermita Iztapalapa Avenue, a main thoroughfare in the heart of Mexico City. The area functions as the assembly and launch site for the country's largest ever TBM.

At 10.2 m in diameter, the Robbins EPB is the first machine of its kind to be fully assembled initially at the jobsite. The TBM will excavate sections of the Mexican Federal District's first new metro line in ten years, travelling between the southern neighborhoods of Tláhuac and Mixcoac. Once complete, the 24 km long Line 12, known as the "Gold Line", will cut commute times from more than three hours by bus to just 25 minutes.

The route of construction winds between existing utilities and structural foundations of the existing city buildings, travelling through some of the most difficult geology in the world.

Tunneling an Ancient Lakebed

Modern Mexico City was founded in 1524, on what was once an island in the middle of Lake Texcoco. The now-drained lakebed sits in the Valley of Mexico, consisting of geology so unique that beyond Mexico City it has only been observed in one known analog in areas of Japan. Buried, long extinct volcanoes in the area have deposited volcanic rock, such as tuff, along with gravels and boulders. Ground conditions along the route of the city's new metro line consist of soft clay interspersed with sand, gravels, significant ground water, and large boulders up to 800 mm in diameter.

"We decided on an EPB after analysis of the geotechnical data, which showed that soft clays were predominant in the area," says Ismail Benamar, Tunnel Manager for Ingenieros Civiles Asociados (ICA). ICA. EPB machines are capable of handling the mixture of soft ground with large boulders

Left: The Robbins EPB is the first of its kind to be assembled at the jobsite

that is expected during tunneling.

The ground is not the only challenge—the project's location at the city centrer is in close proximity to a number of structures. The planned route will pass within 1.5 m of a 4 m diameter collector sewer, within 2 m of building foundations, and just 3.5 m below the metro's active lines 2 and 3. At one point, the tunnel will also pass between two supports of an existing freeway highway bridge, with about 6 m of distance between the TBM and bridge pile foundations.

Tunnel cover is shallow, ranging from just 7.5 m at the launch site to about 14 m between stations. "We have an extensive monitoring program using piezometers and other meters on the surface, underground, inside the tunnel, and in the most critical structures next to the tunneling line," says Benamar. The risk of surface subsidence and vibration can also be controlled by regulating the rate of advance and controlling earth pressure at the front of the machine, as well as the backfill grouting pressure.

Above: **OFTA can save about 70-80% of the time required at a shop**
Right: **The country's largest ever TBM**

Downtown Machine Assembly

The machine build was accomplished in about ten weeks using Onsite First Time Assembly (OFTA). The Robbins-developed method has been shown to save time and money for the contractor, particularly for larger diameter machines.

The method allows TBMs to be initially assembled on location, rather than in a manufacturing facility. "With proper project management and fit up of components, OFTA can save about 70 - 80% of the time required for a similar assembly at a shop," says Benamar.

"It's like receiving many boxes of parts in the mail, and assembling an entire car from those components. It might sound difficult, but with the right quality control everything fits together very well and there is no need to call the manufacturer," says an engineer at the jobsite.

Assembly began in late October 2009 using components manufactured in the U.S., Mexico, Japan and China. Back-up gantries were initially assembled at the surface prior to barge shipment of TBM components. Larger structures including the 133 metric tonne cutterhead support with main bearing were transported to the jobsite by truck.

Critical subsystems, such as the electrical and ventilations systems, were tested before being shipped to the jobsite. Multiple quality control measures ensured precision components and proper fit up. These measures include inspection of all sub-suppliers, who must use a template when manufacturing components.

Components were lowered into the 17 m deep launch shaft for assembly inside a 14 m wide by 34 m long concrete cradle. Assembly began with "inner core" components including the cutterhead support and screw conveyor. Then the upper and lower halves of both the front and rear shields were lined up with welding ports in the cradle, used as a space for crew members to weld the pieces together. The front and rear shields are connected by articulation cylinders for active articulation in curves. Machine components were not assembled directly on the concrete cradle, but on two rails at 60 degree angles. The rails were then used to push the machine to the tunnel face at startup.

Dynamic Design

The Robbins machine was engineered for changing ground conditions, with a soft ground cutterhead, variable frequency drives, convertible muck removal system, and two-stage, ribbon type screw conveyor to handle large boulders and high groundwater levels.

Adaptable Muck Removal

At the start of excavation, the EPB will utilize a sludge pump for muck removal. The sludge pump allows loose, clayey, and water bearing soils to be moved to the surface through a system of pipes. Linear force is applied with pistons to push water through the pipes and cycle the mixture to a settlement system at the surface.

"The system of settlement pools takes advantage of the length of the jobsite," explains the engineer. Pools are arranged linearly down the jobsite and sit at different levels. Once sludge is pumped into the first pool, solids settle at the bottom and begin to fill the container. Excess water drains into a subsequent pool at a lower level, until muck fills this pool and the fluidized mixture flows into a third container. The action is much like that of a gradual waterfall. Once muck fills the pools, solids are scooped up with a pay loader. Water is then recycled back

Above: **Onsite assembly of the TBM**

through tubes to the bulkhead, where it will be added at the face for increased ease of tunneling.

The final 30% of tunnel excavation is expected to consist of more compacted sands and gravels with large boulders. As sludge pumps cannot be used with material greater than about 8 inches 200mm in diameter, the muck removal system will be switched out for a belt conveyor and muck cars. The switchover to a belt conveyor can be done in as little as one hour, allowing spoils to empty into single-track muck cars for removal from the shaft.

Boulders will be disposed of through an initial 1,200 mm diameter ribbon-type screw conveyor. Large pieces of material travel up the center of the screw and exit out of the boulder collecting gate, while more fluidized muck continues on to the secondary shaft-type screw conveyor for conventional removal by machine belt conveyor.

Ground Consolidation

Additives will be employed as needed to condition the tunnel face through six independent injection ports. The independent lines consolidate the flow of muck and reduce the risk of clogging, which can lead to uneven wear of the cutterhead and cutting tools.

"Since the first 70% of the tunnel is in soft clay, we are hoping no additives will be needed besides water for the sludge pump. In the last 30% of tunneling, we may need to use foam to consolidate ground and maintain pressure at the front," says Benamar.

The foam, consisting of water, surfactant, and additive, also reduces the required cutterhead torque as well as overall machine wear. If more watery material is encountered, the foam additive can be switched out with a bi-component consisting of polymer and epoxy. The bi-component increases cohesiveness of the soil by promoting clumping.

Reducing Subsidence

Initial tunneling will begin under just 7.5 m of cover in watery soils at high risk of surface subsidence. The potential problem will be controlled in a number of ways. The contractor will decrease the machine's rate of advance using variable frequency drives. For the remainder of the excavation, the EPB cutterhead rotation will be kept low (around 1.5 rpm at maximum), in stark contrast to the higher speeds (around 10+ rpm maximum) used in similar diameter hard rock TBM tunneling.

In hard rock, high rpm results in fast advance, while in soft ground high rotational speed can result in ground disturbance and surface settlement of non-self-supporting geology. In soft ground, the same result of high advance rates can instead be achieved by increasing the cutterhead torque and thrust, which increases the instantaneous rate of penetration.

As the machine advances, it will line the tunnel with 400cm thick universal concrete segments in a 7+1 arrangement. A two-liquid back-filling system will be used to quickly stabilize the annular space between the tail shield and concrete segments. The liquid mixture consists of cement plus an accelerant, which are combined in the tail shield and harden rapidly after injection. Because the two liquids are kept separate, high pressure concrete pumps, which can disrupt the surrounding geology, are not needed.

Carefully Coordinated Launch

Machine launch began in February 2010 following a commissioning ceremony. At startup the machine excavated using umbilical cables connected to back-up gantries at the surface. Due to the small shaft size, about 34 m long by 14 m wide, only the machine and bridge gantry were assembled at the shaft bottom. The machine then advanced forward approximately 355 m before the first backup gantry was lowered down. Successive gantries were lowered down until the machine had advanced forward 70 m, clearing room for the sixth and last gantry.

"The true benefit of the onsite assembly and coordinated launch is that it has initiated good cooperation between the manufacturer and customer. The teams have worked together to solve problems and keep the project on schedule," says Andrei Olivares, Project Engineer for Robbins Mexico. A team of field service technicians will remain at the jobsite to operate and monitor the machine throughout the project. All tunneling is expected to be complete in 2011. T&T

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Excavating near existing CI linings

In this paper submitted for the 2009 BTS Harding Prize competition Anmol Bedi of Mott MacDonald and Imperial College, London, proposes a hybrid method of predicting the response of existing cast-iron (CI) linings to adjacent excavations, as are in progress and planned in many locations including stations of the London Underground metro network.

In discussing this situation, this paper provides an overview of a hybrid calculation method developed to assist in the determination of acceptable limits of deflections induced in the existing cast-iron linings. Practical implications of setting trigger limits are considered. Finally, a brief description of recommended instrumentation and monitoring procedures is presented.

Cast-iron linings used on the London Underground (LU) network fall into two categories: bolted and flexible segmental linings.

Proposed improvement schemes may require new excavations extremely close to existing tunnels. This results in stress changes in the ground, thereby inducing various levels of distress in each component of the segments. In order to assess the viability of any proposed excavation adequately, an impact assessment procedure that is able to predict the likely occurrence of distress and its magnitude is required. This is fundamental to understanding the response of the existing cast iron linings to the new excavation. Implementation of this procedure in the design phase allows forward planning of mitigation measures, rather than reliance on measures reactive to site observations.

Proposal

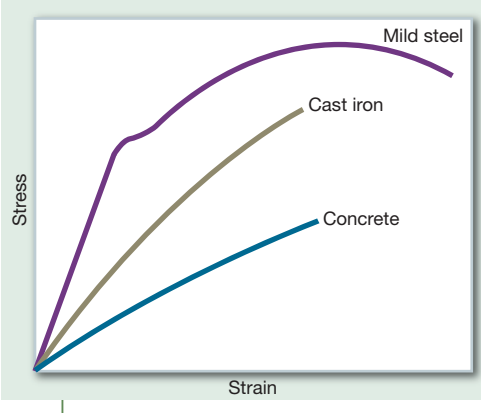
The author believes that current design and construction practices either utilise overly simplified closed form solutions or complex and time consuming numerical analyses, to determine the impact of new excavation on the existing cast iron linings. Furthermore, these design practices do not effectively consider the complete array of failure modes of the cast iron linings which may occur on site, particularly at the radial joints, or at which stage of construction it is likely to occur.

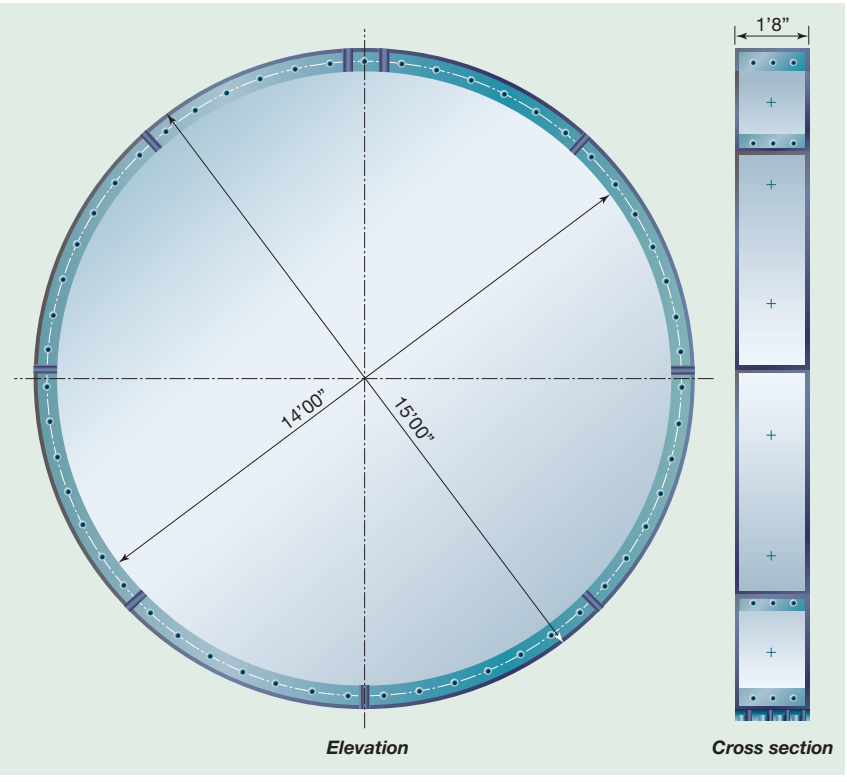
Properties of cast iron

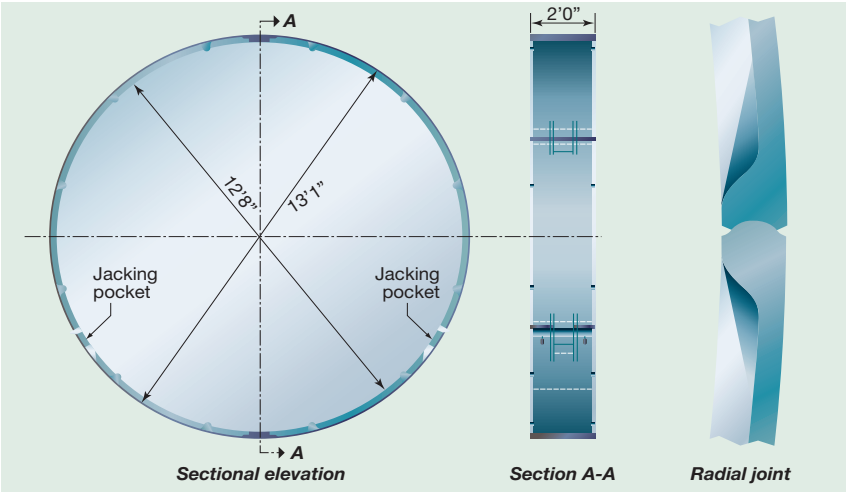
The load-deflection response of cast iron can be idealised as liner-elastic with failure occurring through brittle fracture (Fig. 1). The mechanical properties of cast iron used in the manufacture of tunnel segments throughout the LU network are highly variable and mainly dependent on the grade of cast iron and quality of castings.

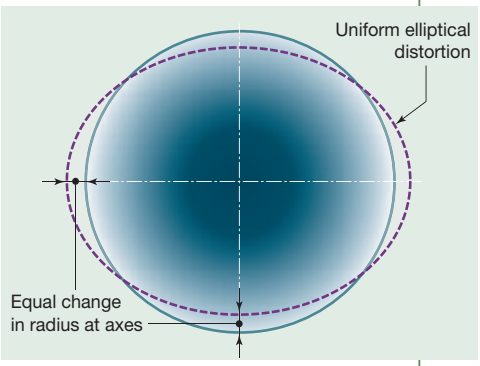
The variability arises from fabrication variables in shear. There is a possibility of small voids (known as 'holidays') in the casting at the junction of flanges and skin, as the greatest thicknesses occur at these

Below: **Figure 1 – Typical stress-strain curves for various construction materials**
Right: **Figure 2 – Typical arrangement of bolted lining (detail not included)**









Left: **Figure 3 – Typical arrangement of flexible radial joints**
Above: **Figure 4 – Uniform elliptical distortion mode**

positions. The rate of cooling of the molten iron is dependent on thickness, and thinner sections either side of the junction tend to cool and solidify quicker leading to 'holidays' as the junction material contracts later. This leads to development of residual stresses, which occur in all cast materials, which are tensile. Cast materials having a tensile strength far lower than in compression. Hence, failure in cast iron tunnel linings is likely to occur from exceeding the tensile stress of the material in flexure, and these failures will be sudden.

Bolted linings

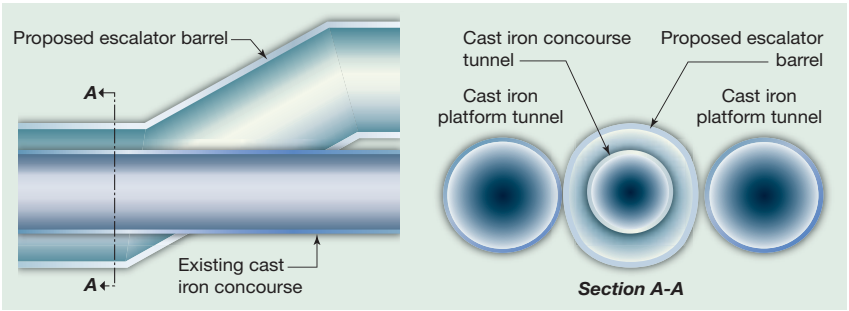
The complete ring of a bolted segmental lining comprises a number of individual segments and a smaller key segment used to lock the ring in place during construction. Figure 2 shows a typical arrangement of a 14-ft. (4.27-m) bolted concourse tunnel ring.

Each segment is profiled in a parallel flanged channel shape in cross section in the circumferential plane. The ends of the segments are closed with a cast-in end plate, forming the radial joint. The radial joints are provided with three boltholes, generally in one or two rows, for bolting one segment to the next during erection. The end plates are normally of a machined finish to provide a flush bearing surface to increase the water-tightness of the rings with, caulking grooves provided at the intrados for further seepage mitigation.

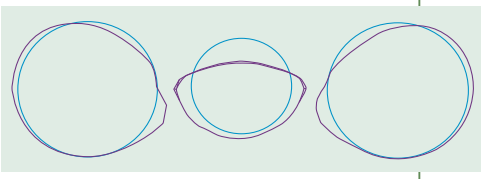
Hoop forces are transmitted between adjacent segments via the flanges or skin. Bending moments may be transferred across the radial joint.

Flexible lining

A cast-iron flexible lining embodies the expanded ring principle of erection, designed for use in conjunction with a suitable shield. The primary difference between the flexible and bolting linings geometry is radial joints. The ends of the segments are provided with semi-cylindrical bearing surfaces, alternately concave and convex (knuckle joints). (Fig. 3). These faces are accurately machined in parallel providing a reliable seal. The knuckled radial joints ensure that moments are not transmitted across the joints.



Above: **Figure 5 – New escalator barrel in longitudinal section (above) and cross section (below)**



Above: **Figure 6 – Deformations due to adjacent tunnelling predicted by finite difference computer analysis (FLAC3D 3.10 program)**

Impact of adjacent excavation – tunnels

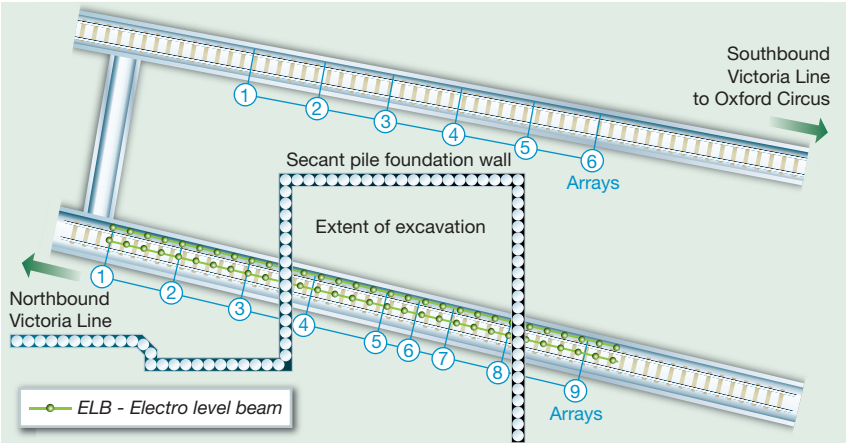
Deformation of segmental linings manifests itself through rotation of each segment at the radial joint, axial shortening and flexure of the segment itself.

The shape distortion of an existing tunnel due to neighbouring construction will be highly dependent on the geometry of the proposed tunnelling works. For instance, excavation of new tunnels immediately adjacent to existing cast iron linings will result in local stress variations around the periphery of the existing linings. Induced distortion in the linings is highly likely to be non-uniform, and may vary significantly from the elliptical mode of distortion conventionally assumed (Figure 4).

An example of one such situation might be where a new escalator barrel is to be constructed to access an existing concourse between two platform tunnels. (Figure 5.)

In this example, the construction of the escalator barrel requires demolition of the existing concourse tunnel and its enlargement for the lower machine chamber.

It is likely that the complex sequencing and geometry of such work would result in a distorted shape of the cast-iron linings far from the conventional assumption in figure 4. This was confirmed using a numerical model using the 3-dimensional finite difference program FLAC3D. Figure 6 shows the results of a section taken immediately ahead of the proposed escalator barrel headwall.



The second and concluding part of this paper will appear in the next issue of *Tunnels & Tunnelling International* covering the response of flexible cast-iron linings response, the proposed hybrid technique of stress assessment with analytical and numerical solutions, allowable deformation, instrumentation and monitoring.

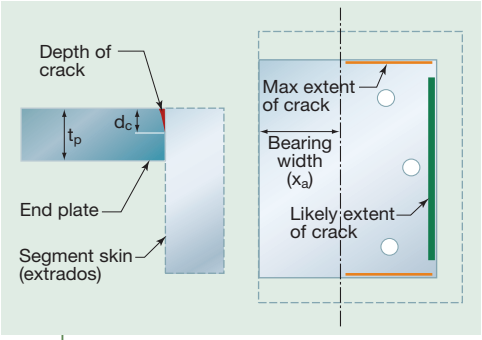
Impact of open-cut excavations on cast-iron linings

The unloading caused by an open-cut excavation and the installation of large-diameter bored piles has the potential to impose asymmetric redistribution of ground loads leading to joint rotations.

A specific example described in Vaziri et al 12, is the excavation for the BBC (Broadcasting House) development in London. This project utilised a 750mm-diameter secant pile wall, propped excavation over the running tunnels of the existing Victoria Line metro. The secant piles are within one metre of the northbound Victoria Line with the base of the excavation approximately 5m from the extrados. The northbound tunnel is constructed from 12ft.8in. (3.86-m) id flexible linings with the southbound tunnel made of bolted linings.

Above: Figure 7 – Plan of the BBC Broadcasting House box excavation adjacent to the Victoria Line running tunnels (Vaziri et al)

Below: Figure 8 – Crack propagation in end plate



Modes of failure - Distress in bolted linings

As can be seen from figure 6, the actual joint rotations may well be in excess of those in uniform ovalisation. Large rotations at the radial joints may result in overstressing various radial joint components such as flexural failure of the end plate, yield or rupture of the bolts and bearing failure in the flange tips or skin. Failure in the segment cross section is exhibited by moment failure. At excessive levels of rotation eventual buckling of the ring will occur.

Joint rotation leads to an increase in moment to be carried across the joint as well as additional moment in the segment cross section resulting from eccentric transmission of the hoop force. With the radial bolts engaged, tension in them will develop proportional to the magnitude of joint rotation. The tensile force is also responsible for bending stresses developing in the cast-iron end plate. Either the bolts will be the first component to fail in tension or the end plate will fail as a result of flexural stresses exceeding the tensile strength of the cast iron.

A common approach to avoid over-stressing of the radial joint is to loosen the radial bolts prior to commencement of the adjacent tunnelling works. While this would eliminate the potential for cracking of the end plate or bolt yielding, there are other practical implications. Firstly, the loosening of the bolts significantly reduces the joint rotational stiffness. This leads to larger joint rotations at the lower levels of distortional stress. That is, higher levels of deflection of the tunnel lining will result due to adjacent excavation. These deflections will occur at an increased rate than if the bolts were tight.

Cracking of end plate: At a level of rotation where the extreme tensile stresses in the end plate are reached, a crack will develop in the end plate. Crack initiation further reduces the bending stiffness at the joint thereby increasing rotation at the joint, tension in the bolts and hence bending stresses in the end plate.

Once the flexural tensile strength of the cast iron is exceeded a crack will develop as shown in figure 8. Continued deflection will result in this crack propagating to full depth and toward the intrados.

Bolts: While the material of choice for the segments was cast iron, the bolts used in the London Underground network are usually mild steel. Where the behaviour of the cast iron is idealised as linear-elastic, with failure occurring through brittle fracture, mild steel exhibits linear-elastic behaviour to a clear yield point and a ductile, non-linear plastic elongation post yield.

As the joint rotation continues, the bolt will elongate elastically until yield is reached. At this level of joint rotation, the factor of safety against the bolts reaching their ultimate tensile strength is generally still relatively high. Further deformation will result in a plastic response of the bolt at an accelerating rate of rotation until the bolts rupture.

Stresses in flange tips: Axial forces and hence compressive stresses are transmitted in the hoop direction through the flanges or the skin. Compressive bearing stresses at the flange tips are generated at relatively high levels of joint rotation in a squatting mode. As the joint rotates, the flange area in contact between adjacent segments reduces thereby increasing the bearing stress.

Moment failure of segment: If bolts are loosened or removed, or the radial joint fails, no tensile force can be transferred across the radial joint. Rotation at the radial joints in this condition leads to eccentric moment in the segment cross section.

Accounting for the axial flexibility of the segment, joint rotation results in a finite compression area at the flange tips. The eccentric moment is proportional to the axial force present in the tunnel lining. At the levels of axial force present in linings at typical depths in London Clay, it is unlikely that the moment capacity of the segment will be exceeded. T&T

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UK's ability to muster resources

With a heavy programme of tunnelling work ahead of it, the UK industry gathered in the ICE Telford Theatre in December to debate its ability to rise to the challenge. Hosted, appropriately, by the BTS Young Members, a packed audience of all ages and affiliations discussed an issue that has generated significant discussion among junior and senior members and is encompassed by the motion: This house believes that the UK tunnelling industry has the sufficient range of engineering expertise and resources to meet the challenges of future projects. As the meeting unfolded, nationalism, internationalism, ageism, and historic reference, all came into the discussion as Neville Harrison (Consultant) and Harnaik Mann (Arup and Vice-Chair of the BTS Young Members committee) proposed the motion and Jon Banyai (Mott MacDonald and Chair of the BTS YM Support Group) and John Edwards (Morgan Est) presented the opposition.

Contrary to the norm, the meeting started with a vote. Kate Cooksey, Chair of the BTS Young Members and host of the meeting, asked for a vote to judge the current feeling on the subject. A show-of-hands judgement was a 60/40 split against the motion - that this house believes that the UK tunnelling industry has sufficient range of engineering expertise and resources to meet the challenges of future projects.

Speaking from an experienced construction and design point of view, semi-retired Neville Harrison (Consultant) presented the historic perspective as seconder for the motion, stating that modern tunnelling began in the UK. From the time of building canals to support the industrial revolution, to building of the railways and the earliest sewers, and from the Brunel's first subaqueous Thames Tunnel endeavour, British engineers advanced development of shield tunnelling; introduced cast iron and precast cast concrete segmental linings; invented and patented early slurry tunnelling systems; and established the specific profession of bored tunnelling with in civil engineering. This was out of a need to get the tunnel job done in the first instance, argued Harrison, and with tunnelling engineers from the UK finding employment on some of the largest tunnelling projects around the world.

As stated by all the speakers, Harrison was first to site the damage of project inconsistency but argued this in a positive spin. He acknowledged that a lot of lessons learned were lost during the tunnelling industry drought of the 1970s and early 1980s but that "during that time we were busy exporting expertise around the world – to Singapore, Hong Kong, North America, Australia. In Cairo, for example, where UK construction and engineering companies were building the deep sewer tunnels, we convinced the French companies working at the same time on open cut construction of the city's first metro line that tunnelling was the way to go and open cut for the metro hasn't been used again. In the same way, said Harrison, "the UK profession has been quick to adopt and adapt international developments, such as SCL techniques and robotics, to suit our needs." A more constant programme of tunnelling work by major agencies and government would be more efficient, he said, "but we have always been able to react to the workload, drawing back British engineers working overseas and attracting foreign engineers, contractors and workers to meet the challenges as they arise."

Opening the cause for the opposition, Jon Banyai ((Mott MacDonald and Chair of the BTS YM Support Group) first acknowledged that Harrison "had 20 years of experience before I was born" and that it was a "cheek" to suggest that he was wrong, "but Neville is wrong". Banyai explained how, of his class of civil engineering graduate from University College London in 2001, only a handful were UK citizens; only 20 of the 80 graduates stayed in UK engineering, (most attracted to lucrative careers in the City); and that only two are known to be working in tunnelling today. "This followed the dire situation of the recession of the 1990s when there were fewer students in civil engineering and when engineering schools, departments and courses were shutting down." This has led to a serious generation gap, said Banyai, a gap that is being filled by either older engineers, younger engineers, or engineers from abroad. Older engineers "could have a job until you die" he said, but "you are more experienced; more expensive; maybe less motivated to fill the generation gap themselves; and are often too busy to train younger recruits". Younger engineers are "less experienced, less expensive, more risky, and likely to go about reinventing the wheel if not taught the old methods." Recruiting from abroad "is not a long term strategy" and in fact, not only are foreign graduates going home, young engineers are being "coaxed away from the UK to places with better weather, more attractive standards of living, and better recognition of the engineering profession". He ended with a plea; to

accept there is a generation gap and to make available resources and funds to get the experience and knowledge out of the heads of the older engineers to help the younger engineers be successful in their tunnelling careers.

Proposing the motion, Harnaik Mann (Arup and Vice Chair of the BTS YM) opened by championing the BTS Young Members as an "enthusiastic crop of young engineers bringing in fresh blood to the industry", including "a growing cohort of women engineers", and said that there is no such thing as a 'UK industry'. "The tunnelling industry has been global for some time and just as other markets, including Far East, Australasia and the Americas, have drawn in resources from the international pool when needed, so can the UK, by keeping our market open and competitive. Joint ventures formed with 'foreign' firms on projects such as CTRL and Crossrail have shown this". In addition to mentioning the UK's "world class research", he also supported the idea of a national infrastructure bank that would operate much like the European Investment Bank to divorce infrastructure spending from politics and allow strategic planning of major projects to avoid peaks and troughs in the workload.

Seconding for the opposition and speaking from the contracting sector of the industry, John Edwards (Morgan Est) agreed that "Brits have been very flexible in the past" but "have we stretched the elastic too far this time?" He stated that the British effort for the Channel Tunnel in the late 1980s drew in foreigner resources to fill gaps in the UK industry and after large water schemes and the Jubilee Line Extension in the 1990s, pressures on UK resources eased until CTRL and cable tunnels and others increased them once again in the mid-2000s. Foreign resources were relied upon once again to meet the demand and the lack of younger engineers coming through the ranks in the UK industry was increasingly apparent. "We are once again in a downturn but with a tremendous workload ahead of us. In the London area alone these include Crossrail; Thames Tideway and its Lee Tunnel starter contract; London Underground disability access and upgrades at Victoria, Tottenham Court Road and Bond Street Stations; along with more National Grid and electricity cable tunnels. Nationally there is the Preston and Brighton stormwater projects and an intense programme of nuclear power station construction in development. This represents about £9 billion of pure tunnelling work in the immediate future. This is a quantum leap when you consider that demand over previous years has been about £200-300 million per annum."

Post war UK tunnelling manufacturers

Preistley
Lawrence
Greathead
Markham
Decon
Howden
NEI

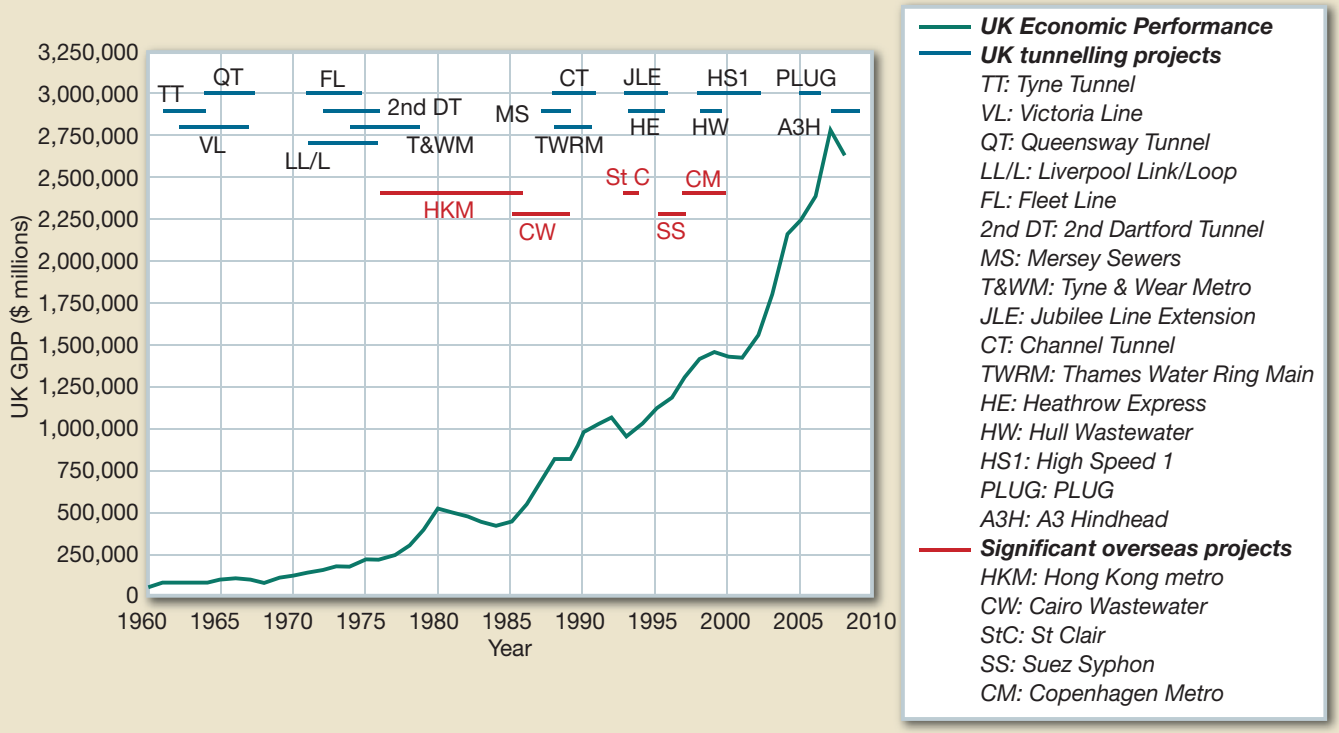
None of these companies now exist

Edwards concluded by making three salient points.

- "Our clients still do not appreciate the limitations on our resources and the current peak is being exacerbated by the on-going delay in awarding contracts.
- Modern legislation, client requirements and bureaucracy place far greater demands on the number of engineers needed on any particular project.
- Several coming projects including Crossrail, "involve a high volume of SCL work that is particularly demanding on quality engineering expertise".

At this point, the debate was opened to comments from the audience.

Below: Inconsistency in UK tunnelling workload was used to support both sides of the arguments

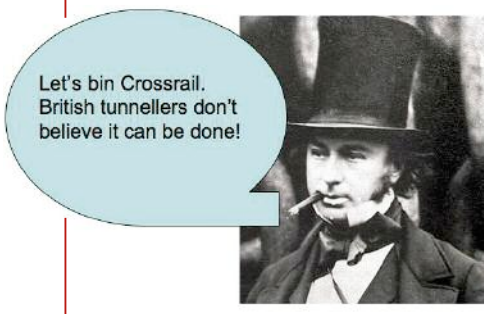


Post war main UK tunnelling contractors

Waddington
Kinnear-Moodie
Mitchell Brothers
Brand
Costain
Lilley
Edmund NuttallMowlem
Buchan / Fairclough
Cementation
Sir Robert McAlpine
Taylor Woodrow
Balfour Beatty

Current large UK tunnelling contractors

Costain
Morgan Est (Millers & AMEC)
John Murphy & Sons
Mowlem
BAM Nuttall
Balfour Beatty



Mike McConnell, Retired contractor: "I will be voting against the motion. The UK will need to joint venture with internationals to get the coming workload completed."

Paul Glass, Kier: "There is no way we can admit that we don't have the resources to get the projects completed. The motion doesn't say that resources and expertise have to be UK sourced. We can get resources from anywhere in the world. Resources are not all about people but also about technological capabilities which reduce the manpower needs in modern projects."

John Edwards: "We shouldn't want to admit it, but many here are 10 years from retiring and others are already 10 years into retirement. The Crossrail Academic Forum is established to address the problem and get more people involved in tunnelling."

Philip Moore: "Contractors have the biggest stretch. The government should be worried. Tunnelling is an international industry and that operates as a reversal of talent as well."

Lacy, Balfour Beatty: "Like Brunel and others of the past, engineers today need to be more flexible, going from bridges to tunnels to other civil projects. European civil engineers are more flexible. Can it be the same over here?"

Harnaik Mann: There is definitely scope for structural and geotechnical engineers to bridge the gap (the last BTS Harding Prize winner started as a structural engineer). We shouldn't be looking in narrow terms at just tunnellers; other disciplines will rise to the challenge as well.

David Kellett, Hunter Personnel: "We have about 28,000 people on our books looking for placements. Of these 14,000 are mining engineers and about 5,000 are tunnelling engineers. Of these less than 6% are under the age of 30. The level of risk to be shouldered by tunnelling engineers is also high. That's not the same in banking."

Tim Harman, Costain: "We have lost engineers and if contractors are not hiring, nobody is coming into the industry."

Neville Harrison: "Get the jobs going and that will attract people. I suspect that resources will fit the demand. We have a 10 year time frame to work with and should schedule the work load accordingly."

Kate Woolley, Mott MacDonald: "What about pay? It's not enough for attracting young engineers."

Colin Mackenzie, Retired constructor: "There could be an 8-10% increase in pay for engineers without a dramatic impact on the cost of tunnelling." (SW - This comment needs checking)

Helen Nattrass, Robert McAlpine: "Engineers are problem solvers. As a young engineer I became involved in tunnelling when the company I worked for won a tunnel contract unexpectedly. It was baptism by fire, but I got on with the job and quickly became familiar with the new work. All our young engineers are problem solvers, and I believe that, even without prior specialist experience they will step up to the mark should they become involved in tunnelling work."

Matt Sykes, Arup: "We are doing youth a disservice. Things have changed. Yes there is more risk involved. Yes we are relying on the experience of older engineers, but the project director of the new HSBC Bank building in Hong Kong was 32. I have great faith in the confidence of young people, great faith in the young members of the BTS, and great faith in the older members to support them. I am for the motion. We will have sufficient range of engineering expertise and resources to meet the future challenges."

Summations and vote

Spirited discussion was called to a close with John Edwards summing up for the opposition. "The opposite team have argued our case. We have "muddled through" in the past. We do have a great history and technology has, and will continue to reduce labour needs, but we are losing the lessons learned by the lack of new recruits into the industry. There are plenty of foreign engineers but are they part of the UK industry? There is not the resource in the UK at the moment to face the tremendous workload in the immediate future. Vote against the motion."

Harnaik Mann closed for the motion. "Take a look around the walls of the room for a moment. The names of Brunel, Bazalgette and many others would not be here if they lacked faith in the industry and decided to give up. What if a young engineer took the same attitude in their civils interview? Is pessimism the hallmark of a chartered engineer? If you don't support the motion, then perhaps you might like to sign this petition? It tells the government to bin Crossrail and HS2 because BTS hasn't got the conviction to see these through. We are a profession of problem solvers, and have achieved great things. Conditions aren't ideal, but we are excellent at our jobs. Support the UK tunnelling industry and vote for the motion."

After a show of hands, Chair Kate Cooksey declared the result as slightly less against the motion, the gap having narrowed from the vote at the start the meeting to about 55/45. Two things missed was to get some idea of audience numbers in the different age groups; and to record a demographic split for those who voted for and against the motion. That too would have contributed tellingly to the result. T&T

Rapporteur: Shani Wallis

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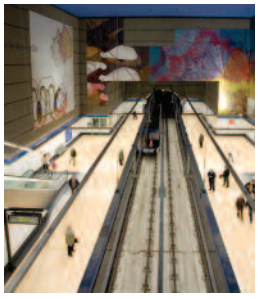
Channel Tunnel Rail Link

Nuevos Ministerios, Madrid



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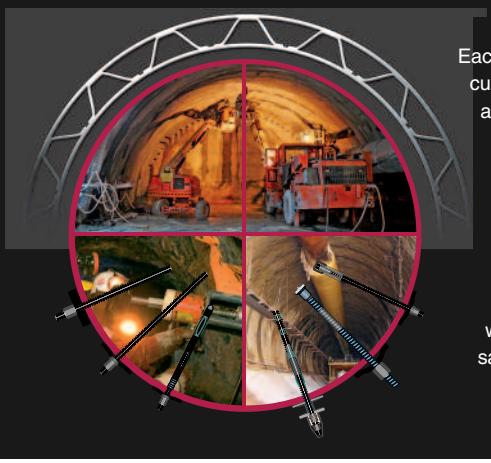

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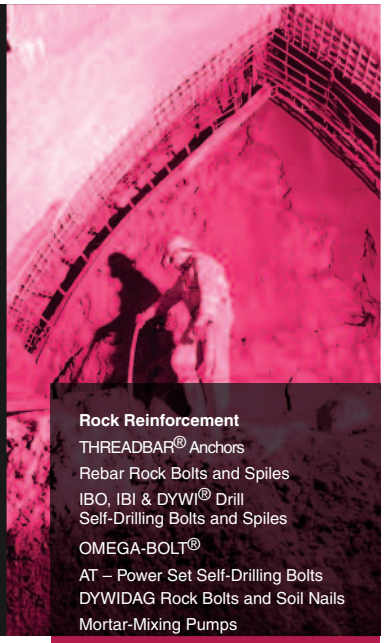

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Meeting shotcrete specifications

In the long history of shotcrete, or sprayed concrete, linings underground, never has so much been expected of them. In the transition in scope from hard rock primary support to soft ground permanent support, shotcrete is now expected to create structures under even more demanding conditions, but still at comparatively low cost. Here technical editor Maurice Jones reviews the state of some developments designed to meet such demands.

Understandably in view of the recent economic situation, development of hardware has been minimal lately. One of the most advanced concepts, the Meyco Logica automatic application robot, was introduced a few years ago and seems to be most often applied to spraying on waterproofing membranes or fireproofing mortars, but is a valuable addition to tunnellers' capabilities for more accurate and consistent linings at lower cost.

Hardware manufacturers have been concentrating on improving customer service, gaining experience and increasing their share of an increasingly global market. What hardware development there has been is mainly in improved control systems and monitoring of performance, as customers usually want records of the work done. The Logica now has an improved ergonomic and automatic control system to operate the Robojet-based manipulator with eight degrees of freedom. A laser scanner is used to measure the tunnel profile and consequently allow calculation of the standoff distance and nozzle angle.

For medium-to-large tunnelling projects requiring anything but localised shotcreting there is little alternative to wet-mix, mechanised sprayed concrete to meet production requirements. Equipment such as Meyco's wide range for different excavation dimensions and deliveries, Normet's Spraymec range and the Putzmeister/Sika models are mainly designed for efficient underground use.

Service first

Frequently improving customer aftercare involves co-operation with a major, complementary manufacturer in a non-competing activity. The joint marketing of Sika (materials) and Putzmeister (equipment) is now well established. Last year Meyco BASF made a global co-operation agreement with Sandvik Mining & Construction for tunnelling and mining. Initially this covers co-operation on sprayed concrete machinery servicing.

Normet has also been strengthening its international coverage, particularly in tunnelling. Normet's build-up over recent years produced its best ever sales year in 2008 and, despite the subsequent downturn, is well positioned technically and logistically to serve tunnelling more widely.

Above: **A Meyco Logica 15 automatic spray robot applying a Fireshield membrane**

Which materials?

Similar to hardware, materials manufacturers have come up with little new, although Mapei of Italy, which operates a specialist underground division (UTT), maintains seven major research centres for all products. Some 5 per cent of its sales revenue and 12 per cent of employees are in to r&d. Most suppliers have been concentrating on marketing, and meeting customer expectations, including specifications and codes. Exceptional development trends include more use of polymers (see page 44).

After several years of trying to persuade specifiers of the viability, if not advantages of macro-synthetic fibres (as opposed to micro-synthetic fibres for fire resistance) in shotcrete, suppliers such as Elasto-Plastic Concrete (EPC) and Propex (Fibermesh 650) are now beginning to gain major orders for both primary as well as secondary reinforcement. EPC's Andrew Ridout reports more large orders from the US and Norway, as well as Japan and Australia.

Of course steel fibre suppliers such as Bekaert are not taking the challenge lightly

Above: **One of two Putzmeisetr-Sika SPM 500 PC wet-spray concrete manipulators used on the B29-Schwäbisch Gmünd bypass tunnel for a thick shotcrete lining sealing below the water-table.**

and emphasise certain performance characteristics which, they say, make steel fibres a better choice for shotcrete reinforcement. The debate and fibre characteristics will be covered in more detail in future issues of *T&TI*.

There are now many standards covering the ingredients, methods of application and testing of sprayed concrete (shotcrete) structures. The most recent include:

- BS EN 13670:2009 – Execution of concrete structures
- ISO226966:2009 EDTN1 – Execution of concrete structures
- BS EN 934-2:2009 – Admixtures for concrete.
- BS EN 1504-9:2008 – Products and systems for the protection and repair of concrete structures.

In addition, the European Federation for Specialist Construction Chemicals (EFNARC), drew up a specification and guidelines in 2008 for thin spray-on liners for initial stabilisation and sealing.

Context

There has been much discussion over many years about how shotcrete should be used in tunnel lining. The fully designed sprayed concrete lining (SCL) approach was developed in response to the more *ad hoc* observational approach of traditional NATM in deciding what type of support (albeit pre-designed) to use, usually involving various levels of reinforcement and thicknesses of shotcrete.

A particular extension of SCL is the CombiShell lining developed by Miller Tunnelling (now Morgan Est) and Beton u Monierbau (now Alpine BeMo Tunnelling). Used on the London Heathrow Airport Baggage Tunnel, the concept has been further developed by these two partners with Mott Macdonald as LaserShell, used on the Heathrow Terminal 5 Tunnel and London King's Cross rail station redevelopment. It employs TunnelBeamer laser profiling of the excavation and shotcreting to achieve the designed tunnel lining profile in soft ground.

Skills

Even though mechanised shotcreting has the advantages of virtually tireless application from comfortable operator positions, it still requires considerable operator skills, unless the process can be totally computer controlled in a robotic operation. Even then manual intervention may be necessary.

Below-par skills have led to 'shadows' in applied shotcrete around obstructions such as around support materials or rock projections. There may also be a lack of uniformity in application of layers, requiring return visits to meet the specification.

For these reasons, in addition to health & safety, proper education of operators has become a major priority for contractors and promoters. The result is a drive to establish nozzleman training and certification in various parts of the world. The efforts have been mainly national with, for example, the American Shotcrete Association organising certification with the American Concrete Institute running training and including schemes in other countries such as Singapore. At the end of last year, the Sprayed Concrete Technical Committee of EFNARC launched its own Nozzleman Certification Scheme. It does not cover training but an examiner assessment course is being run by CUC for EFNARC at the Hagerbach Test Gallery, Switzerland.

Alternative approaches

At the start of a project the twin emphases in providing sprayed concrete have to be on long-term design performance and cost control. However, with the many unexpected problems that can develop during construction, suppliers are often called upon to provide fast solutions. This may involve re-examining other approaches.

For example, the dry-mix shotcrete process has been largely restricted to small tasks, repair work, and small excavation dimensions that make the use of wet-mix equipment difficult.

In addition to promoting the benefits of not using the apparently ubiquitous shotcrete additives, Phil Richardson claims other advantages for the dry-mix Natural Cement (NCD) shotcrete that his company distributes. "It's ironic that our shotcreting capabilities have been largely ignored," he reports, "but now we are being called in to help with waterproofing problems."

The company's Shotcrete 513 and 530 mixes are designed for fast setting and high early strength, especially in wet and cold conditions. "Thus where other products have failed in the presence of flowing water," claims Richardson, "ours are able to adhere to the surface with early, and continuous, strength build up. As well as helping to deal with water, the Shotcrete fast cure can save projects a lot of time. With Shotcrete 513 we can achieve 5MPa compressive strength at 15 minutes – that's about 25 minutes after spraying – with 65MPa at 28 days. Compared to other dry-mix processes there is less rebound and dust make. "

Its inertness has resulted that Shotcrete 513 has met strict specifications for use in association with water supply and aquifer work. Galeforce Engineering used it to stabilise limestone in canal tunnels in the English Midlands. Managing director John Aveling said, "In addition, due to its waterproofing and water-stopping properties, it has also been utilised for areas of substrate with severe water egress such as piled walls and tunnel linings and has proved very effective in difficult circumstances, even as far as having been sprayed onto flowing water."

NCD Shotcrete mixes have been used in the Hindhead Tunnel lining by Balfour Beatty to cover leaks from end-of-shift joints in the support lining. Also, in trials with contractor Morgan Est the material stopped leaks of up to 2-bar pressure.

Richardson claims distinct advantages from not employing additives in the right concrete mix. "With no modification to the mix, we can eliminate the 'idiot factor' in preparing for shotcreting," he claims, "and because the material is natural we have no waste disposal problems." He also says that serious consideration has to be given to the effects of all current concrete additives may have on future generations.

Natural Cement Distribution generally recommends the Lancy Tubaflow shotcrete equipment and, when shotcrete reinforcement is required, Bekaert Dramix steel fibres to increase tensile strength. The compact Lancy Tubaflow air-operated, trailer-mounted unit for both wet- and dry-mix spraying, has pumped over 650m. T&T

Saving sustainably - polymeric binders for tunnel support

Many existing tunnels need repair, and there is an increasing demand for new ones. Particularly critical are time and material consumption. Newly developed polymer-modified sprayed concretes saves both time and materials – thanks to much reduced rebound. Klaus Bonin, Dr Jürgen Bezler and Frank Gregory of Wacker Chemie describe their development and application trials

As described below, large-scale tests prove that polymer-modified shotcrete slashes costs for tunnel lining construction, and offers additional properties such as water-proofing properties and increased adhesion on difficult surfaces.

Sprayed concrete is a construction material of major importance, and its technical requirements are high. It must provide the desired strength, stability and impermeability. However, application specialists from Wacker Chemie had an additional idea; they wanted to reduce rebound during spraying while also making the sprayed concrete water resistant. They developed polymeric binders for sprayed concrete to be used in tunnel construction. First tests in practice in a new tunnel for a salt mine proved the efficiency of the new product.

Less rebound

An important quality factor in the performance of sprayed concrete is rebound. Rebound excess material cannot be reused and must be disposed of as waste. Reducing rebound is therefore important for both technological and economic reasons.

The newly developed product line Etonis ensures a major enhancement in rebound properties. Moreover, Etonis-modified sprayed concrete has some additional interesting concrete properties. Besides outstanding processability without the risk of separation, it offers good compaction characteristics and high compressive strength. The polymer-modified sprayed concrete adheres excellently, even to difficult substrates such as wet tunnel walls and has an improved carbon dioxide resistance. The new polymer binders can be shipped in either liquid or powder form.

Development tests

First experiments started more than four years ago in Wacker's application labs for construction materials in Burghausen, Germany. Based upon many years of

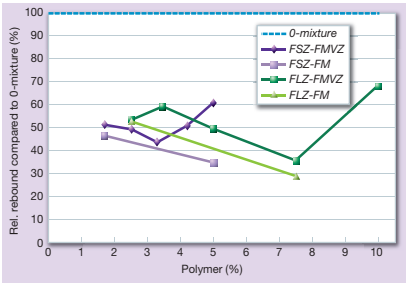
Below: Analysing tunnel shotcrete core samples in the Wacker Chemie Burghausen applications lab to determine the sprayed concrete's waterproofing properties and its strength increase over time

Table 1

Reduction of rebound, consequent time savings
(data from Hagerbach test gallery tests, Switzerland)

	0-mixture	CEM-A 5	CEM-B 8	CEM-B 5
Theoretical volume of shotcrete (m3 - no rebound)	10 400	10 400	10 400	10 400
Design mix – including rebound [m3 shotcrete]	11 954	10 968	10 845	10 744
Costs of supplying shotcrete [CHF/USD]	2 582 069 2 383 405	2 917 528 2 693 053	2 884 672 2 662 725	2 857 851 2 637 968
Costs of transporting rebound within construction site [CHF/USD]	3108 2869	1136 1049	889 821	688 635
Costs of disposal of shotcrete rebound [CHF/USD]	38 851 35 862	14 204 13 111	11 116 10 261	8595 7934
Total costs of shotcrete [CHF/USD]	2 624 028 2 422 136	2 932 868 2 707 213	2 896 677 2 673 807	2 867 134 2 646 537
Shotcrete SAVING [CHF/USD]	0 0	-308 840 -285 077	-272 649 -251 671	-243 106 -224 401
Time saving for shotcreting [days]	0	42.2	47.0	50.8
Construction site cost saving [CHF/USD]	0 0	4 223 907 3 898 920	4 699 593 4 338 006	5 079 540 4 688 720
Net profit [CHF]	0 0	3 915 066 3 613 841	4 426 944 4 086 335	4 835 948 4 463 870

Above: Spraying polymer-modified concrete onto a tunnel wall in the Stetten salt mine to stabilise the tunnel and prevent water leakage.
Right: Figure 1 – Relative rebound v concentration of polymer (data from Hagerbach gallery tests, Switzerland)



experience using polymers in mortar applications, a variety of polymer binders in sprayed concrete formulations have been analysed and tested intensively. The first development tests were designed to determine the amount of polymer that reduces sprayed concrete rebound and still provides the desired concrete properties.

The tests were carried out in the Hagerbach Test Gallery in Switzerland, to work out the effects of polymer on the properties of the concrete compared to a commercially similar, arbitrarily selected reference mixture. Various wet-spray concrete formulations were applied in standardised tests to study their effects on the sprayed concrete's properties. Design of experiments was carried out to determine the parameters needed for the planning of the next level of tests. Two to three cubic metres of concrete were sprayed in each trial. To ensure a homogeneous mixture, only midstream concrete was used.

In the course of the investigations it became apparent that the addition of the new polymeric binders significantly reduced rebound. As indicated in the figure below, tests with polymer-modified concrete formulations show that with increasing amounts of polymeric binder, the rebound first declines, reaches a minimum and then increases again (Fig. 1). The figure shows a comparison between the solid powder polymer FSZ and the liquid polymer type FLZ, relative to the reference mixture (0-mixture). Additionally, two different plasticisers were tested; a standard plasticiser FM and a combination of plasticiser and retarder FMVZ.

In general sprayed concrete loses aggregates through rebound, which causes the cement concentration in the applied sprayed concrete to rise. As the cement concentration rises, the strength of the concrete increases as well. Therefore, rising rebound equates to increased ultimate strength. Due to process reasons, most convenient were the concrete formulations that had been modified with liquid polymeric binders.

Tunnelling application

To test the new product under realistic conditions, large-scale testing had to be done. An adequate opportunity was given when a new access gallery was built in a salt mine in Stetten (southwestern Germany), which is owned by Wacker Chemie. In 2007 the construction of a new, 905m-long access route allowed standard road trucks to pass through the tunnel. During the construction work the underground construction workers had to penetrate the impermeable layers above and below the rock. There they came across groundwater. Usually, very soon after blasting, concrete is sprayed onto the exposed rock. Unfortunately fresh concrete does not stick effectively to wet tunnel walls. That's where the novel polymer-modified sprayed concrete proved its additional value-added characteristics.

For this large-scale application aqueous polymer was used for the concrete mix. Inspection of the sidewall surfaces revealed that the standard sprayed concrete (Figure 2 - right) exhibited a large number of wet patches. In contrast the polymer-modified sprayed concrete (left) demonstrated much better adhesion to the wet substrate, did not show any wet patches and proved to be less prone to crack formation.

In addition to the decrease in rebound these trials showed that the polymer-modified sprayed concrete leads to improved adhesion on wet ground and to an increased impermeability against water. Thus the new polymer-modified sprayed concrete did not only stabilise tunnel walls, but is also a promising solution to impregnate the tunnel walls and to provide a barrier against water leakage.

Conclusion

The tests in the tunnel confirmed significantly less concrete ended up as rebound on the tunnel floor. It came as an important additional effect that the polymer-modified sprayed concrete also adhered better to wet walls and provided a superior shield against wetness in the tunnel.

Polymer-modified concrete thus possesses valuable potential, both technical and commercial. The additional costs of modifying the sprayed concrete are offset by the time and material saved, and converted into significant profits (Table 1).

The polymer-modified sprayed concrete is easy to handle and versatile; it can be applied vertically to tunnel crowns, is suitable for both tunnelling and mining, as well as for slopes and canals or culverts. In all these applications the novel Etonis–brand polymers for sprayed concrete speed up construction and reduce system costs immensely. Furthermore they reduce the amount of further additives required in the formulation.

With its waterproofing properties and reduced rebound, the polymer-modified sprayed concrete is a promising and cost-cutting solution for many infrastructure projects like tunnelling and underground construction. T&T

Polymer additives

Wacker developed its first dispersions as mortar and concrete admixtures as early as the 1920s. In 1957, WACKER pioneered polymeric binders in powder form for the construction industry. This technology revolutionised working methods in the sector, providing the first ever one-pack polymer-modified cementitious system. Today, with its dispersible polymer powders and dispersions marketed under the brand names Vinnapas and Etonis, Wacker is one of the world's leading manufacturers of products for the modification of cementitious systems.

The benefits that polymer additives bestow on the end product include easier processing, excellent anchorage to all substrates, increased flexibility and flexural strength, and enhanced weathering resistance. Another advantage is that none of Wacker's dispersible polymer powders and dispersions contain plasticisers, and therefore have low emission levels. The main applications of polymer-modified premixed mortars are construction and tile adhesives, exterior insulation and finish systems, self-levelling mortars and grouts, as well as plasters and repair mortars.

Wacker Polymers has production sites in Germany, China, Korea and the US, as well as a global sales network and technical centres in all major regions.

RECRUITMENT

WEBSITE DIRECTORY

Dates & Events

17-19 MARCH 2010
ISTSS 2010 Frankfurt, Germany
The 4th International Symposium on Tunnel Safety and Security. Manuscript abstracts should be submitted to the Secretariat by 01 June 2009, poster abstracts by the 01 October 2009. Contact: Anders Lönnermark, SP Technical Research Institute of Sweden; tel: +46 10 516 56 91; email: anders.lonnermark@sp.se; web: www.sp.se

18-19 MARCH 2010
4th China Tunnel Summit, Shanghai, China
Among the key issues of this summit will be: World & China tunnelling development trends; Hard rock TBM issues & solutions in city subway tunneling; subsea tunnelling and speeding construction. Contact: email: marketing@merisis-asia.com; tel: +86 21 62478898; fax: +86 21 62478838; web: www.merisis-asia.com/tunnel2010

19-25 APRIL 2010
Bauma 2010, Munich, Germany
The 29th International Trade Fair for Construction Machinery, Building Material Machines, Mining Machines, Construction Vehiclesand Construction Equipment will be held in the Messe Muenchen Messegelaende 81823, Munich, Germany. Contact: email: info@bauma.de; tel: +49 89 949 11348; fax: +49 89 949 11349; Web: www.bauma.de

2-7 MAY 2010
North American Society for Trenchless Technology No-Dig 2010, Chicago, USA
The 2010 NASTT No-Dig show will be held at the Renaissance Schaumburg Hotel and Convention Center, Chicago. The conference theme is "Rebuilding North America's Underground Infrastructure Using Trenchless Technology" and will include infrastructure investment; social costs and impacts; industry trends, advancements and new concepts. Contact: NASTT; web: www.nodigshow.com

14-20 MAY 2010
2010 ITA World Tunnel Congress, Vancouver, Canada
Not long after the 2010 Winter Olympics, the International Tunnelling Association (ITA) visits the spectacular city of Vancouver, British Columbia, for its yearly conference and exhibition. The usual combination of working groups, open sessions and technical talks will all be included. Contact: web: www.wtc2010.org

19-21 MAY 2010
Tunnel China, Shanghai
With a focus on China 'The most dynamic market for the tunnelling and underground space industry in the world' the event will look at railway and highway developments and feature trenchless technology. Contact: web: www.tunnel-china.org

8-10 JUNE 2010
InterTunnel 2010, Turin, Italy
Tunnelling exhibition aimed specifically at clients, contractors and consultants involved in the construction of and equipping and operation of tunnels. Contact: Mack Brooks Exhibitions; web: www.intertunnel.com

9-11 JUNE 2010
Swiss Tunnel Congress, Lucerne, Switzerland
Tunnelling developments in the Apls will doubtless be a talking point at the Swiss Tunnelling Society's STC. The event will be held at the KKL Lucerne. Contact: fgu@thomibraem.ch web: www.swisstunnel.ch

14-16 JUNE 2010
International Conference Underground Construction Prague 2010 Transport and City Tunnels
The Czech ITA-AITES Tunnelling Association will host its 11th International Conference at the Clarion Congress Hotel Prague. Lectures will be simultaneously interpreted into English, German and Czech. Contact: Czech ITA-AITES: tel: +420 266 793 479; email: ita-aites@metrostav.cz; web: www.ita-aites.cz

15-17 JUNE 2010
European Rock Mechanics Symposium (EUROCK 2010)
Eurock 2010 is an ISRM Regional Symposium of Europe. The Symposium covers all the aspects of rock mechanics and rock engineering. Contact: Jean-Paul Dudt, Laboratory for Mechanics of Rock (LMR). EPFL-ENAC-LMR Station 18 CH-1015, Lausanne; tel: +41 21 693 23 25; fax: +41 21 693 41 53; email: lmr@epfl.ch; web: www.lmr.epfl.ch

19-23 JUNE 2010
North American Tunneling Conference, Portland USA
The 2010 NAT will be held at the Marriott Downtown Waterfront Hotel in Portland, Oregon. Conference and exhibition information and registration is available on the SME web site. Contact: Society for Mining, Metallurgy and Exploration (SME); web: www.smenet.org.

12 - 16 SEPTEMBER 2011
6th International Symposium on Sprayed Concrete, Norway
Sixth International Symposium on the modern use of wet-mix sprayed concrete for underground support will be held in Tromsø, in the north of Norway. Contact: Siri Engen The Norwegian Society of Graduate Technical and Scientific Professionals - Tekna; fax: +47 22 94 75 01

28 SEPTEMBER 2010
Tunnels and Tunnelling Conference
T&T, in partnership with the British Tunnelling Society will be bringing you the most important conference event of the year. With a special focus on the current and future technical developments in tunnelling construction along with a global view of tunnelling activity, the T&T conference promises to fill you in on everything you need to know heading into 2011. The conference will be held at the ICE in London. Contact: email; conference@tunnelsonline.info; tel: +44 (0) 20 7936 6848

21 OCTOBER 2010
Sir Alan Muir Wood Memorial Symposium
The British Tunnelling Society is presenting a symposium on tunnelling and geotechnical themes with papers looking at recent tunnelling case histories, risk, and the inter-relationship of current design and research. Confirmed speakers include, prof Robert Mair, Prof John Burland, Prof David Muir Wood, Robert Muir Wood, prof Paul Jowitt and Martin Knights. Contact: bts@event-logistics.co.uk

3 - 27 OCTOBER, 2010
ISRM international Symposium 2010 and 6th Asian Rock Mechanics Symposium, New Delhi, India
Contact: Mr. V. K. Kanjlia, Member Secretary, Indian National Group of ISRM: tel: +91-11-2611 5984/2688 2866/2410 1591; fax: +91-11-2611 6347; email: uday@cbip.org/ cbip@cbip.org; web: www.arms2010.org

BRITISH TUNNELLING SOCIETY

17 MARCH: **Gotthard Base Tunnel Project - Switzerland, Transco Sedrun**
Michael Gutzeit & Hans-Juergen Bartschat of Bilfinger Berger Ingenieurbau will give a presentation on the challenges faces on the Gotthard Base Tunnel project. Please note this is a Wednesday meeting. ICE, 6pm fpr 6.30pm start.

15 APRIL: **Harding Lecture – Risk vs Innovation**
Alistair Biggart presents this year's Harding Lecture. ICE, 5.30pm for 6pm start.

20 MAY: **West Ham Flood Alleviation Scheme**
Andrew Morgan of Costain will presents the West Ham Flood Alleviation Scheme. ICE, 5.30pm for 6pm start.

A DATE TO REMEMBER...

If you know of a tunnelling related conference, event, seminar or exhibition that is not listed here, we would be delighted to hear from you. Please contact the editor by post, email, fax or through our web site: Editor, 'Tunnels & Tunnelling International', John Carpenter House, 7 Carmelite Street, London, EC4Y 0BS, United Kingdom. Fax: +44 20 7936 6826 Email: editor@tunnelsonline.info Web: www.tunnelsonline.info

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