

tunnels & tunnelling

INTERNATIONAL

APRIL 2010



Special report: Asia Pacific
T&TI looks at the tunnel boom in Asia with drainage schemes in Hong Kong and metro plans in Ho Chi Minh City

Technical: Open face excavation
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comment

Show me the money

Politicians are not going to win votes by raising taxes. As the UK is in the run up to one of the closest general election races of recent times, we should not pin too much hope on winning work from government funded projects. Fears remain about the likelihood of major tunnelling schemes in London going ahead. It is rare that a drink in the BTS bar doesn't involve one tunneller or another doubting the future of the Lee Tunnel, the Thames Tideway or Crossrail – the in depth news piece on page 18 will tell you more about the issues surrounding Crossrail.

None of this is unique to the UK of course. But with an election just around the corner there is a building anxiety among the tunnelling community. If we can't force the outcome of the election, or force the hand of the victor (I'm sure the BTS lobby group will be doing its best) then perhaps we should have a backup to publicly funding projects.

It was recently put to me that Singapore has found one solution to the problem. It is well known that when a new infrastructure link is built, be it a motorway, metro or other, the areas benefiting from the new connection see increases in property values and business. However, other than through higher taxes, a government would find it difficult to cash in on this new money and recoup its investment in the link.

When building its metro, Singapore bought up land on the outskirts of the city and continued the line a station or two further than necessary into this area. The value of the land soared with the new connection and the government was able to recoup some of its investment.

The UK has in fact gone one step further on a tunnel project in South West London. The Northern Line Extension to Battersea is employing some unusual funding solutions. The project owner Treasury Holdings knew early on that it would not get any government funding. Treasury Holdings is developing Battersea Power Station and the surrounding area to create a large, office, residential and commercial complex.

Battersea has no underground connection so for the development to be a success a link was needed. To fund the USD 800M the owner looked to the financial services for inspiration and worked out a structure that allowed it to borrow from future earnings. The project will be financed by money borrowed against future ticket sales, council tax and a levy on other developers that will benefit from the connection.

Finding private funding methods has proved a popular trend in the construction sector, and indeed others. Finding private funding in a recession may need a bit of imagination.

Jon Young

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On the cover

A view down the west bore of the Hong Kong West Drainage Tunnel (page 39)



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T&T goes into detail on what you can expect from Bauma

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NEXT MONTH:

T&T is taking a look at tunnelling works in Northern Europe, including the tunnel under St Petersburg's flood protection barrier.

On the technical front, we'll be going into depth on waterproofing methods, looking at the latest trends and developments.

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HONG KONG

Excavation begins on TWDT

Ex cavation on Hong Kong's Tsuen Wan Drainage Tunnel (TWDT) began last month.

Seli's double shield TBM was pushed into the launching chamber in order to produce more room and to allow the assembly of other back-up gantries.

The project is being completed by the Maeda, CRGL, and Seli joint venture.

TWDT will be excavated in extremely strong and abrasive unweathered rocks, including crystal ash tuffs of the volcanic group, the Tai Po Granodiorite, and a variety of cross-cutting dykes, including basalt, rhyolite, fine-

grained granite, and quartz.

The high strength and abrasiveness of these rocks and the presence of zones of blocky and closely jointed rock will yield difficult conditions for the TBM.

Pre-excavation grouting will be required over much of the tunnel length to meet the specified groundwater control criteria.

TWDT will require, among other structures, the construction of a 5.1km long circular profile tunnel with a minimum operational internal diameter of 6.5m lined with 300mm thick steel-reinforced precast concrete segments.

The TBM is equipped with a

robust cutting-head to cope with the hard formations and is also equipped with probe drills to investigate the rock and water ahead of the tunnel face.

The head is equipped with 47 19-inch (482mm) cutters and is powered by eight 315-kW motors. The TBM breakout torque is 6600kNm.

TWDT will alleviate flood risk in the Tsuen Wan district by intercepting excess channel flow in three stream valleys to the north of this area of Hong Kong.

Right: The TBM is equipped with probe drills to investigate the rock and water ahead of the face



BRITAIN

Bell Common Tunnel upgrade scheme opened

The scheme to upgrade the Bell Common Tunnel on the M25 in Essex was officially opened at the beginning of March.

The GBP 91M (USD 137.2M) project was completed two months ahead of schedule and was opened by Transport Minister Chris Mole.

The project forms part of a major government investment to improve journey time reliability and safety on Europe's busiest motorway. The work included resurfacing the carriageway through the 515m long tunnel and

installing improved lighting and ventilation. Fire safety systems were also replaced, as well as CCTV cameras installed to help traffic officers spot and take care of incidents in the tunnel more quickly.

Chris Mole said at the opening, "I am delighted that this major upgrade has been delivered two months early."

Chris Mole officially opened the tunnel at a ceremony on the top of the tunnel, between junctions 26 and 27 of the M25 near Epping. The work began in October 2008.

INDONESIA

Jakarta to start building sewage tunnel in 2011

The city administration in Jakarta, Indonesia, has announced that it was building a new sewage tunnel system.

The scheme will channel household liquid waste to a plant that will recycle it into raw water.

The project is being carried out in partnership with the central government.

The government will use a IDR 3.8 trillion (USD 412.5M) loan from the Japan International Cooperation Agency for the initial construction of pipes and the plant.

"We chose a foreign loan

because the private sector cannot afford to fund an infrastructure project on this scale," Governor Fauzi Bowo told reporters after meeting with representatives from the Public Works Ministry at the start of March.

The city will provide IDR 700 billion (USD 76.2M) of the total cost.

Construction is expected to start next year. Workers will construct the central zone project via a 1.8m diameter pipe.

The whole scheme is expected to be operational by 2020.

USA

Bellevue council supports tunnel

Bellevue City Council in Washington agreed last month to support a light-rail tunnel in the city.

City staff drafted a letter to Sound Transit supporting a tunnel that will run along 110th Avenue Northeast.

The cost of the tunnel exceeds the

budget for that section of East Link, the light-rail line that will run from Seattle to Overlake. City manager Steve Sarkozy explained ways the city could cut project costs.

The cuts included contributing back to the project additional sales-tax and business-tax revenues the

city receives as a result of the light-rail project, helping to make city property along the route more affordable. The cuts would be worth between USD 104M and USD 150M.

He said that Sound Transit staff could cut costs by applying savings

from other parts of the line.

Last year, the council endorsed a tunnel that would run underneath 106th Avenue and would have cost some USD 600M more than East Link's budget. Sound Transit staff then began studying the shorter and cheaper 110th Avenue tunnel.

CANADA

Big Becky's Niagara progress

The TBM digging a third hydro tunnel under the city of Niagara Falls passed the 6km point on its 10.2km journey.

The TBM, named Big Becky, is operating 90m below Stanley Avenue just south of Highway 420. Big Becky averaged more than 11m progress per day in February.

About 20 workers are currently busy at the tunnel portal assembling the equipment needed to install the arch lining. This equipment will be about 450m in length.

The tunnel lining will consist of a

layer of sprayed concrete, installed at time of boring, a waterproofing membrane and a permanent 600mm thick concrete liner of unreinforced, cast *in situ* concrete. Construction of the arch lining is due to begin this spring.

Crews are now beyond the 4km mark of the invert lining.

Work on the intake structure, located at the International Niagara Control Works (INCW), about 2km upstream from the Horseshoe Falls, was suspended for the winter but is due to resume this



Big Becky has passed the 6km mark on her 10.2km journey

month. Later this year, well in advance of Big Becky's arrival, workers will build the reinforced

concrete intake structure within the cofferdam and rock cut on the upstream side of the INCW.

NEW ZEALAND

Auckland best tunnel route

Auckland's central rail tunnel project was accorded a preferred route last month. However, a business case has yet to be made for construction funding.

The more than NZD 1bn (USD 708.8M) tunnel's plan will see it run between Britomart and Mt Eden.

A NZD 5M (USD 3.5M) investigation study for KiwiRail and the Auckland Regional Transport Authority identified a 3km route including locations for three new

underground stations. The route will rise to a height of 70m.

Consultants narrowed down the route from three short-listed options described to the Auckland Regional Council in February.

KiwiRail chairman Jim Bolger said the preferred route required fewer curves than the other options, meaning lower costs for a boring machine and better operational speeds offering greater fuel economy for electric trains.

The route has the added

advantage of running beneath public roads rather than private property for 2.4km.

Transport Authority planning chief Peter Clark said an estimated cost range of NZD 1bn (USD 708.8M) to NZD 1.5bn (USD 1bn) had yet to be narrowed as part of a business case to be developed in association with concept design work over the rest of this year, before KiwiRail decides whether to seek a notice of requirement to protect the route.

BRITAIN-GERMANY

Eurotunnel plans to link Britain to Germany

Plans to run high-speed trains to Germany through the Channel Tunnel were being discussed last month. German transport operator Deutsche Bahn was liaising with Eurotunnel to consider the idea of running the high speed trains to London and Frankfurt, two main financial hubs of the continent.

Eurotunnel chief Jacques Gounon said, "I do believe that Deutsche Bahn is fully convinced there is a role to play between Germany and London."

Guonon also revealed that Eurotunnel was in discussion with Deutsche Bahn about lifting limitations on the length of the train, as the German operator prefers shorter trains than Eurostar.

"It will take time and will need some simplification in the tunnel, but we want to do that and Deutsche Bahn is a serious player in this game," said Gounon.

BRITAIN

UK Parliament discusses high speed rail

The secretary of state for transport in the UK Lord Adonis addressed the House of Lords last month on high speed railways between London and the major cities of the Midlands, the North and Scotland.

Adonis said, "This Y-shaped network of about 335 miles (539km) in total, with branches north of Birmingham running either side of the Pennines, would be

capable of carrying trains at up to 250mph (402km/h) and could be extended to other cities and to Scotland."

The transport secretary argued that the project was financially viable: "With the project yielding more than £2 (USD 2.96) of benefit for every £1 (USD 1.48) of cost, HS2 Ltd (High Speed2) estimates the capital cost of the first 120 miles (193km) of the line from

London to the West Midlands at between GBP 15.8 and 17.4bn (USD 23.4 to 25.7bn). This is broadly similar to the cost of Crossrail." He added, "The cost per mile beyond Birmingham is then estimated to halve."

Adonis said Heathrow must be linked to the line: "It is important that Heathrow is connected to any high speed line ... via an 11 minute direct service"

LAOS

Laos gets first ever TBM

The first TBM ever to excavate in Laos was launched in late February. The 7.6m diameter Robbins single shield TBM will dig a new hydroelectric tunnel for the Theun Hinboun Expansion Project, which will provide power to neighbouring Thailand.

Contractor CMC di Ravenna is constructing the 5.5km tunnel for the project owner Theun Hinboun Power Company, a joint venture of the Laos Government, Norwegian contractor Statkraft, and GMS Power of Thailand.

"We chose the single shield TBM based on ground conditions and the type of tunnel lining needed," said Luca Barbàra, Far East Manager for CMC di Ravenna.

The TBM was designed to accommodate moderate squeezing ground conditions - an articulating cutterhead with

overcutters makes the machine capable of excavating 100mm beyond nominal tunnel diameter. Ground along the tunnel alignment consists of alternating strata of sandstone, siltstone, and mudstone.

To support the ground and provide final lining, 280mm thick, pre-cast concrete segments will be used in a 5+1 arrangement, making a finished tunnel diameter of 6.9m.

The machine was assembled in Robbins' Solon, Ohio, manufacturing facility and shipped to the jobsite along the Nam Theun River, the largest tributary of the Mekong. Machine startup went smoothly, with no significant TBM or equipment problems.

Above: Laos's first ever TBM was launched for the Theun Hinboun Expansion Project

"We are presently excavating at 20m per day, but expect to reach 30m per day as tunneling progresses," said Barbàra.

Other recent progress at the site has included the initial phases of a new 70m high reinforced

concrete dam adjacent to the power station. Crews redirected the flow of the Nam Theun River through a diversion channel in preparation for dam building. Placement of reinforced concrete began in February.



CROATIA

Croatian Diaspora will raise tunnel money

The Croatian diaspora will raise money for the continuation of construction work on the Sv. Ilija (St. Elijah) Tunnel in Dalmatia.

Dalmatians living in Germany and Canada were calling on Croats living abroad to donate at least USD 100 for tunnel construction work.

The 4.29km long tunnel will go through Biokovo Mountain and connect coastal and inland Dalmatia by road. It was scheduled to open in 2012, but its construction was stopped until 2012 for lack of funds.

It will be the fourth largest tunnel in Croatia.

NETHERLANDS

The great escape

A Dutch woman tunnelled out of a Breda prison using only a spoon. The tunnel was 30ft (9.1m) long and ran from the basement of the prison kitchen to the road outside.

In the style of many Hollywood films, she reportedly carried a small amount of dirt from the hole each day and discarded it in the exercise yard.

The Ministry of Justice declined

to reveal details about the tunnel in the fear it could inspire other inmates. She is one of only a handful of people to ever escape from a Dutch prison.

Local media reported that the 35-year old was less than two years from ending an eight year sentence for stabbing her sister-in-law.

The woman is still at large but not deemed dangerous by Dutch authorities.

VIETNAM

Thu Thiem Tunnel gets first underwater segment

Vietnam's Thu Thiem Tunnel received its first immersed element last month. It is the first of four sections that will make up the river crossing.

The 370.8m tunnel forms part of the East-West Highway Project and will connect the city's District

One with the new urban Thu Thiem Area in District Two. The six lane, 22km road will connect National Highway 1A with the Ha Noi Highway in the east, passing under the Saigon River through the new tunnel and relieving traffic flow travelling east to west.

The 27,000 tonne segment will be lowered in to its designated place on the Saigon riverbed and covered in backfill material. The three remaining segments will be towed to the site from Nhon Trach District in southern Dong Nai Province one at a time for the

same process, taking one month each to install.

The Sai Gon East-West Highway Project is being implemented by Ho Chi Minh City with financial assistance from the Japan International Cooperation Agency (JICA).

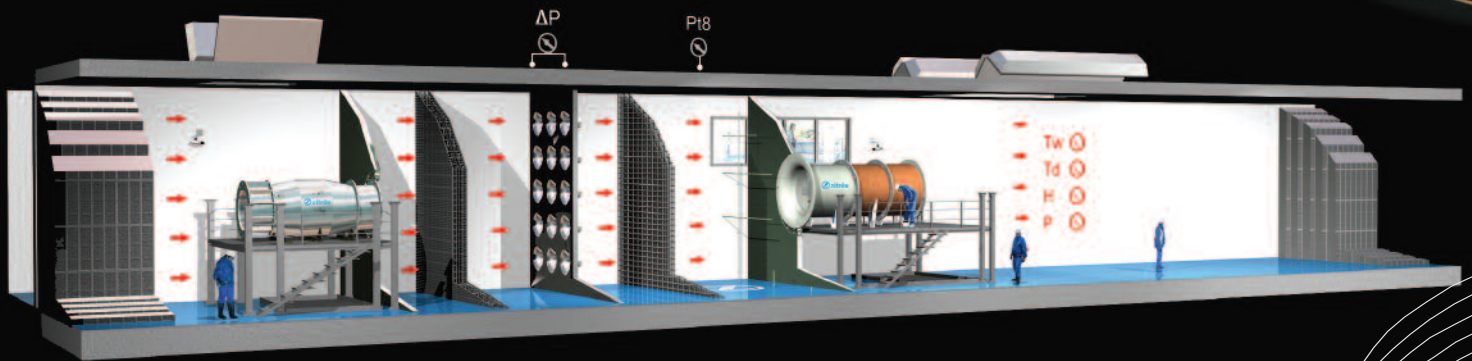
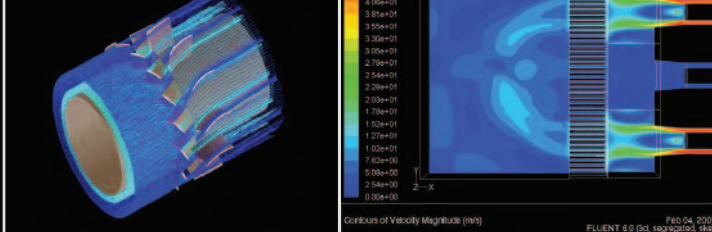
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BRITAIN

Crossrail takes possession of properties

Crossrail secured ownership of all properties surrounding Lindsey Street, London, last month. It means that demolition can now go ahead to clear space for the new

terminal at Farringdon Station. Before all properties were acquired, City of London arranged new accommodation for the displaced residents, which

included the occupants of a shelter for the homeless.

A spokesperson for Crossrail told *T&T* at the site that demolition would begin within a few days of securing the properties, which was going on as *T&T* went to press. All demolition work is scheduled to be finished by the end of Q3 of this year.

According to Crossrail, all evictions took place under amicable circumstances.

Network Rail project manager at Farringdon, Richard Walker said, "Our investment at Farringdon will transform the station into one of London's most important transport hubs, the only station from which passengers will be able to access Thameslink, Crossrail and London Underground services, offering links to four of the capital's major airports (Gatwick, Luton, Heathrow and London City) and the country's two international rail stations (St. Pancras and Stratford)."

When work is completed in 2017, Farringdon will handle over 140 trains every hour.



Left: The Lindsey Street properties have now been secured for demolition

CANADA

Calgary airport tunnel plans

The city of Calgary hopes to build an airport access tunnel, officials said last month, but admitted that it will take several years for the project to happen.

The city and Calgary Airport Authority agreed to a plan to

preserve land access points for the extension of 96 Avenue through a tunnel under the new runway.

The new fourth runway will be built in spring 2011 and the city had hoped to construct the tunnel under it at the same time.

This plan was axed because neither the province nor Ottawa were willing to contribute funding to the project.

Excavation and grading on the new runway and International Concourse will begin in January 2011.

CHINA

Efforts to rescue workers

A collapse in a railway tunnel in China last month left ten workers trapped inside. Rescue workers were working continuously in search of the men, as *T&T* went to press.

The accident happened in Ulangab City, about 150km from the regional capital Hohhot and 400km from Beijing.

More than 300 rescuers and 60 machines were drilling into the rubble, hoping to improve ventilation, and sending in food and water to the trapped workers.

According to reports some 2000m³ of rock and dirt caved in.

The tunnel is part of a railway being built to link Ulanqab City's Jining District and Baotou City.

"We were working in the tunnel when gravel and dust began pouring down," Li Tiying, one of the six survivors, told local media. "We ran, and cried out for everyone else to run with us." When he had escaped to safety, Li said he took one last look at the tunnel and saw dim light inside. "But within seconds, the tunnel was sealed off by stones and sand."

AUSTRALIA

Tunnel pressure forces windows to blow

Passengers on a CityRail train in Sydney narrowly escaped being injured by flying glass last month. The train was going through the Epping to Chatswood tunnel when air pressure caused the window to push out.

Some ten people were sitting in the first carriage of the train at the time of the accident. Student Daniel Rosser told local media that a window pane landed just centimetres from one of his friends.

"All of a sudden the door window from the train flew out at

such a high speed and flew back down the stairs," said Rosser. "It was so close, if it had been a peak hour train it would have been so bad."

"It was an older train and it was air-conditioned so there were no windows open," he continued. "Our ears popped in the tunnel. The pressure was so great in the tunnel we figure it must have pushed the window out."

CityRail will now reinforce door windows on its older-style suburban trains to prevent such an accident happening again.

In a statement, CityRail said the incident was rare, but as an added safety precaution, it will now attach metal fasteners to door windows on all K-set carriages.

The AUD 2.3bn (USD 2.1bn) Epping-Chatswood rail link opened last year and has been plagued by problems, including unacceptably high noise levels.

In 2007 it was revealed that Tangara trains would not be operating on the route because of the steep gradient in some parts of the tunnel.

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DENMARK

Copenhagen's council members at odds with government

Centre-right parties in Copenhagen's City Hall want the Osterbro Tunnel project planned 2014 opening to be postponed in lieu of a larger connection.

A planned tunnel from the Osterbro district of Copenhagen to the Helsingør motorway is insufficient to handle future traffic needs, according to council members from the Liberal, Conservative and Danish People Party.

The parties aired their concerns to fellow party members at parliament, arguing there isn't enough money to adequately fund the project.

The members said the project

risks ending up as a compromise solution that will paralyse train traffic on the regional Coast Line and the S-train lines for several months during construction.

Transport minister Hans Christian Schmidt is sticking to the 2014 deadline for the project, as the original agreement did not include the option to renegotiate.

"We have an agreement with the City of Copenhagen and from the state's side we've delivered our part of the financial contributions," Schmidt said. "So I expect that they can deliver their part of the agreement so the connection can open in 2014."

According to the three parties, the reason is the city's traffic growth rates have not been taken into account, so they believe the project should be put on hold until funding for an extra two lanes can be secured.

The current cost of the tunnel is around DKK 2bn (USD 363.6M). The parties' proposed six-lane connection would cost DKK 5bn (USD 909M), according to the city's technical environment department.

The City of Copenhagen will finance the bulk of the project, with additional financial aid coming from the state.

Liberal Party council member

Lars Dueholm told local media, "A four lane road would be too small when coupled to a harbour tunnel."

"We also believe there will be big problems for the area's residents if we go the cheap route, because the construction will lie flush up against some large housing blocks."

Dueholm also pointed out that national train operator DSB estimated that some 40,000 passengers will be affected daily by the current construction plans. It was also revealed that DSB would expect about DKK 1.8M (USD 327,000) a week in compensation.

News in brief

■ New York tunnel fire

A small, smoky fire ignited in a train tunnel leading to Pennsylvania Station, New York last month but there were no injuries and trains were not delayed, officials said. The cause is under investigation.

■ Albanian tunnel opens

The southern Thirre tunnel in Kalimash, Albania will open to traffic by mid May. The tunnel, part of the 170km Durres-Kukes-Morine highway which links Albania to Kosovo, was closed last October for installation of equipment and stabilization of a short segment.

■ China-Russia oil tunnel

China finished constructing a tunnel under the Amur River on the Russian-Chinese border. The tunnel will carry millions of tonnes of oil. More than 80 Chinese workers dug the 1.9km tunnel in six months.

INDIA

Seli completes TBM for Himalayas

Seli completed construction of the TBM that will be used to bore the Kinshaganga Hydropower Project in India last month. The 6.13m diameter DSU TBM will bore the 14km long tunnel under the Himalaya chain with a cover of between 750m and 1000m.

Geology along the tunnel is mainly made up of different schism formations with the presence of poor and squeezing rock fault zones.

The geology and the high

cover require the installation of 350mm thick reinforced precast concrete segments. The tunnel's internal diameter will be 5.2m

The Hindustan Construction Company (HCC) awarded Seli the subcontract for excavation and the lining. State owned NHPC appointed HCC general contractor for the entire project.

The project involves construction of a 37m high concrete-faced rockfill dam, a headrace tunnel and an underground powerhouse.



Above: The 6.13m diameter DSU TBM will bore the 14km under the Himalaya chain

BRITAIN

Belgian race track collapse

A section of a tunnel that runs underneath the Spa-Francorchamps track which hosts the Belgian Grand Prix collapsed last month.

Nobody was hurt in the incident, although circuit

organisers Spa-Francorchamps were hosting a Club Subaru Belgium event at the time.

Work is now under way to repair a hole that has appeared in the run-off area of the Blanchimont corner, while there is

some damage to the track.

Spa-Francorchamps claimed the tunnel had collapsed due to lack of maintenance. The tunnel was built in 1978.

This season's Belgian Grand Prix will take place on 29 August.

RAIL

Costain Skanska awarded first Crossrail tunnelling contract

The first Crossrail tunnelling works contracted was awarded last month.

The GBP 15M contract to construct the Royal Oak Portal went to the Costain Skanska joint venture.

The Royal Oak Portal is near to

Paddington main line station and will act as the transition ramp for Crossrail trains when entering and exiting the central London tunnels.

Work will begin immediately and the project is scheduled for completion next March.

Chief executive of Costain

Andrew Wyllie said, "We are delighted to have been awarded this first tunnel related construction contract for Crossrail. To be involved in the Crossrail project is a significant step forward for Costain and a valuable addition to our strong rail portfolio."

METRO

Contract award on Kolkata Metro

The contract for the 3km long underground section of Kolkata Metro in India was awarded last month to the Transtunnelstroy and Afcons Infrastructures joint venture. It is the second and final tunnelling contract to be awarded on the 8km underground section of the

15km East West Metro Link.

The USD 206M design and construct contract is for the section between Howrah Maidan Station and Central Station.

Construction of the tunnel will include boring a 520m section beneath the river Hooghly.

According to local media

reports, the TBMs may come from Japan and Germany.

The project was awarded by the client the Kolkata Metro Corporation (KMRC).

The deadline for completion is within four years.

The total cost of the East West Metro Link is USD 1bn.

RAIL

PB awarded three high-speed contracts

Three new contracts to manage high-speed and intercity passenger rail projects in Illinois, Ohio and Florida were awarded last month.

The contracts went to Parsons Brinckerhoff (PB), owned by Balfour Beatty.

The Illinois Department of Transportation (DoT) selected PB as programme manager for the 284-mile (457km) high-speed signature route from Chicago to St.

Louis, with USD 1.1bn in Federal funding earmarked for the project.

The Ohio Department of Transport selected a PB-led team to provide consultant services for the development of a new intercity passenger rail service on an existing rail freight corridor in the Cleveland-Columbus-Dayton-Cincinnati "3C" corridor, a distance of approximately 250 miles (400km). The Federal Railroad Administration awarded the project

USD 400M in government funding in January.

In Florida, PB will lead the consulting team selected by the Florida DoT to undertake the planning and design of a 230-mile high-speed rail line between Orlando and Miami.

The project involves preliminary engineering and environmental analysis, which includes recommending the final alignment and train technology.

RAIL

Crossrail OJEU notice

Crossrail submitted an Official Journal of the European Union (OJEU) notice last month for work at five Crossrail stations in London.

The work will include diaphragm walling, shaft construction, piling and associated works.

Programme director Andy Mitchell said, "These significant pieces of work will be crucial to the Crossrail programme as they will enable each station to receive the Tunnel Boring Machines on schedule at its site."

The five stations are Bond Street, Tottenham Court Road, Farringdon Station, Liverpool Street and Whitechapel.

Up to 14,000 people will be employed at the peak of Crossrail construction in 2013-2015, with an estimated further 7000 jobs created indirectly. Tunnelling work will start in 2011, with Crossrail scheduled to open for service in 2017.

Crossrail is Europe's largest construction project.

RAIL

Indian award

A contract was awarded last month on the new railway line being developed between Jiribam and Tupur in India.

The INR 1.97 billion (USD 43.1M) contract to develop a railway tunnel between Dholokal and Kaimai went to the Hindustan Construction Company and Coastal Projects joint venture.

The project involves construction of a single line tunnel about 3.25km long, including earthwork, slope protection and stabilisation, reinforced cement concrete portal walls, and permanent tunnel support.

HIGHWAY

Proposals invited for Seattle tunnel

Washington state's Department of Transportation (DoT) invited the four contractors bidding for the USD 1bn Alaskan Way Viaduct Replacement tunnel in Seattle to

submit draft proposals, ahead of final bids in May.

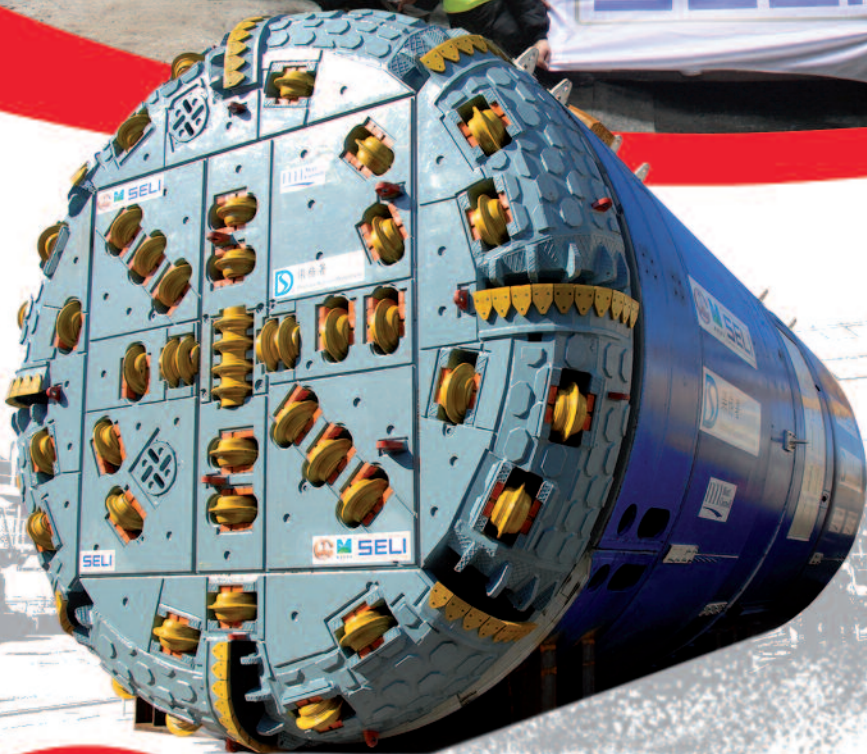
The two mile (3.2km), 54-foot (16.5m) diameter tunnel will be one of the largest bored tunnels on the planet. It is part of the USD

4.2 billion plan to replace the Alaskan Way Viaduct highway and downtown seawall.

The DoT will award the project the end of this year and works could start on site in 2012.



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RAIL

Contract awarded for China high speed

A contract was awarded last month to construct the tunnels and ventilation buildings for a section of the new rail link between Guangzhou and Hong Kong.

The contract, worth EUR 312.6M (USD 417M), went to Leighton, a subsidiary of Hochtief, via its participating interest Leighton Asia. The Hong Kong section of the XRL will be

underground for the 26km from the terminus in West Kowloon to the boundary crossing point at Huanggang, Shenzhen.

The awarded Contract 822 includes the construction of a 7.6 km twin-track tunnel between Tse Uk Tsuen and Shek Yam, ventilation and access adits, two ventilation buildings and a 90 m deep ventilation shaft. Drill and

blast techniques will be used for the construction of the tunnels.

Managing director of Leighton Asia Hamish Tyrwhitt said, "Leighton Asia is delighted to be selected to construct another part of Hong Kong's rail network. The XRL will provide the strategic link for Hong Kong to the comprehensive high-speed rail network in mainland China. Leighton is excited to play a

key role in this effort to provide a fast and convenient railway service to the communities in Hong Kong that will connect to other mainland cities."

Another two XRL contracts went to Maxwell Geosystems to act as an independent consultant and supply instrumentation and monitoring services.

HYDRO

Chinese company to build powerplant in Ethiopia

A contract agreement was signed last month to build a new hydropower project in Ethiopia.

The deal was signed by the Ethiopia Electric Power Corporation (EPEPCO) and Chinese company Gezhouba Group.

The project forms part of Ethiopia's long term commitment to meet growing power demand.

After the recent part collapse of the Gilgel Gibe II plant (T&T, March 2010, p7), EPEPCO began a nationwide power rationing.

The new power project will cost USD 480M and will have a power generating capacity of 254MW

upon completion which is scheduled to be within the next five years. The Genale power plant will boost the country's power capacity by 25 per cent.

Ethiopia has earmarked USD 12bn investment to its 25 year power sector plan.

There are currently six hydropower plants in Ethiopia, supplying a combined 1000 megawatts. The country's power demand, however, is 1200MW.

Ethiopian Prime Minister Meles Zenawi told parliament that the country's power problems would be solved within a few weeks of the announcement.

HYDRO

Cavico scoops hydro job

The contract for tunnel construction at a hydropower plant in Vietnam was awarded last month.

The client Song Bac Hydropower awarded the USD 11M contract to Cavico. Cavico will construct a 4100m long, 3.8m

diameter cross tunnel, with a 143m long and 3.8m diameter incline tunnel, a 315m long adit tunnel, a 73m tall surge tank and a water intake gate.

Construction is expected to be finished within 27 months of the project beginning.

METRO

MTR tunnelling contract

The final major tunnelling contract on Hong Kong's MTR West Island Line (WIL) was awarded last month.

C704, for the drill and blast excavation of the 2.1km twin tube tunnel between Sai Ying Pun and Kennedy Town went to the Gammon and Nishimatsu joint venture. The contract also includes construction of cavern stations at Sai Ying Pun and Hong Kong University.

The award is Gammon Construction's second contract on the WIL, after scooping the USD 170M C705 last month for the cut and cover construction of Kennedy Town Station as well as drill and blast excavation of the overrun tunnel.

Work has already begun on contract C703, the first of the tunnelling contracts, following the its award last August to the Dragages, Maeda and BSG JV.

METRO

Victoria Tube redevelopment

Transport for London (TfL) announced last month that it intends to award the Taylor Woodrow and Bam Nuttall joint venture the contract for redevelopment of Victoria tube station.

A shortlist of three companies was invited to bid for the main construction contract back in 2008, they were the Balfour Beatty and Morgan Est JV, the Taylor Woodrow and BAM Nuttall JV, and the Costain, Bachy Soletanche,

and Laing O'Rourke JV.

TfL Board approved funding of about USD 1bn for the station's upgrade last October as part of the company's investment programme.

The first phase of the project will be the construction of the new North Ticket Hall along with a new entrance.

Work will start next year and is scheduled for completion in 2016. The remainder of upgrade works will be completed by 2018.

SEWER

Morgan Est precast contract win

Ridham Precast, Morgan Est's specialist precast manufacturing facility, was awarded a GBP 4M (USD 6M) contract last month to manufacture and supply 5,420 wide tapered trapezoidal tunnel rings.

The order was placed by 4Delivery, a JV of United Utilities, Costain and MWH.

Each ring is 1m wide with an internal diameter of 2.44m. They will be used in the construction of a new 11km sewer to transfer waste water in East Sussex.



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Above, from right to left: London mayor Boris Johnson; Prime Minister Gordon Brown; Transport Secretary Lord Adonis

Last week's acquisition of properties in and around Lindsey Street in London by Crossrail seemed to send a clear message that the project was going ahead full steam and that the target completion date of 2017 was well within sight.

The Lindsey Street acquisition cleared the way for work to begin on the new terminal at Farringdon Station, which will turn Farringdon into one of London's main transport hubs, giving passengers access to Thameslink, Crossrail and Tube services, as well as links to four of the city's major airports.

However, even now there are those within the industry who are adamant that the project is doomed to failure.

Crossrail has divided opinion ever since the concept was first talked about, with two camps of people disagreeing with each other on the main issue: Will it or will it not ever happen?

A source close to the project told *T&T* that he was far from convinced he'd ever see Crossrail completed. He said that there were a number of problems that could derail the project ranging from bad project management, to funding and the upsetting of local residents.

The source told *T&T*, "With only around GBP 3bn (USD 4.4bn) spent so far on the project that is estimated to cost GBP 16bn (USD 23.8bn), the government still might decide to pull out of the project rather than come up with the extra GBP 13bn (USD 19.3bn)."

He said that he wouldn't be surprised if the expected new government scrapped the plans. "There is a government review planned for the Autumn, regardless of who is in power, where they will discuss the funding for the project."

A Crossrail spokesperson, however, disagreed. She said, "The project enjoys strong cross-party political support and we are confident that this will continue after the general election."

Crossrail claimed that the project will pay for itself in the long run, with the spokesperson telling *T&T*, "Crossrail is a major boost for the economy of both London and the UK. It will create some 14 000 jobs at peak construction and independent research has indicated that Crossrail will deliver some GBP 36bn (USD 53.6bn) in wider economic benefits to the country's economy over the next 60 years."

The source responded saying, "I

CROSSRAIL

Off the beaten tracks

have no doubts that it will pay for itself eventually, but that isn't going to pay for the project when they need the money. Now."

The source added that one reason why Crossrail was not getting the universal support that it would have hoped for was because of some of the public relations issues that have sprung up in the past few months.

Earlier in the year it was claimed in the national press that Crossrail was employing bullying tactics to intimidate residents into selling their homes cheaply, and then delaying payments. It was also claimed that people working for the developer were found rummaging through other residents' belongings after serving notices to enter the properties. This led to the Mayor of London Boris Johnson stepping in to investigate.

The source told *T&T* that he could see one potential trump card for the Crossrail project. He said that during the extension work of the Jubilee Line in the 1990s, the government at one point said that they would pull out of funding the project. As a result of this, the owners of the Canary Wharf complex threatened to sue the government, not only for the cost of the station but also for the tower blocks that had been built up around the area to be serviced by the new line. In the end, the government backed down and provided the funding.

"If the government decided to pull out of Crossrail, history could repeat itself. Crossrail could threaten legal action against the government and then they might think it the better option to put up the money. This could be the saving grace of the project."

Crossrail has been talked about for decades, without any real

progress being made, fueling the sceptics' doubts that it will be stopped again this time.

Famously, the 'Hog in the Pound' pub on Bond Street erected a sign in the late 1970s informing customers that the building was closing down and was scheduled for demolition to make way for the new Crossrail line. The pub still stands.

Crossrail has changed its form many times since it was first proposed. A report by a committee in 1974 recommended, alongside the development of the Fleet Line to Fenchurch Street and the River Line project, two deep-level railway lines, one linking Paddington to Liverpool Street, and another linking London Bridge and Victoria. The cost of these two links, along with the re-opening of the Snow Hill tunnel to form Thameslink, was estimated at GBP 300M (at 1974 exchange rates, USD 697M).

Later, in the early 1990s an east-west route was again proposed. A bill was introduced into parliament, promoted by London Underground and British Rail, and supported by the government, but was rejected by the Private Bill Committee in 1994. This service even went as far as preparatory work on rolling stock, with concept drawings for what was planned to be Class 341 trains released.

A number of alternative routes on the west side were considered, including regional services to Amersham and Watford in the northwest, and Reading in the west. All have now been dropped in favour of the current proposal.

The Crossrail spokesperson told *T&T*, "We are on schedule to deliver this vital new railway in 2017."

Kris Mole



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PIPE REHABILITATION METHOD: STATIC PIPEBURSTING

This case story is based on Gothenburg Water Company – Sweden

The company has used static pipebursting for the past decade, rehabilitating existing water pipes in the Swedish metropolis. This case story explains both the challenges and the experiences made by the administration, and the teams of machine operators alike.



Leif Isaksson, project manager at Gothenburg Water Company, Sweden, has used pipebursting for the past ten years, and still regards it as an unrivalled pipe rehabilitation technique. He explains: "Replacing 40-50 sometimes more than 100 year old water mains in Gothenburg city centre was a challenge, with the density of traffic, the parallel installations next to the water mains in the ground, and the general disturbance to the public."

In 1998, a search for suitable equipment ended up with the purchase of the T40 static pipeburster model from the Scandinavian No-Dig Centre – Denmark (SNDG). We chose this model because of its small 250mm-wide footprint and its round, threaded steel rods with the "positive grip system."

In 2006, the T40 machine had achieved more than 600hrs on the clock, but the package from 1998 was completely original. We traded the T40 pulling rig with a new 2006 model - the T45 pipe burster. We kept the rest of the old 1998 package: power pack and all the accessories, including the steel rod system, which was still flawless.

The T45 pulling rig is an even better model, which to date has more than 200hrs on the clock. My guess is that since we started using this equipment in 1998, we have accomplished the replacement of more than 35,000m of worn-out water pipes up to 315mm diameter in Gothenburg city centre using the very same equipment and accessories.

Today, it is one of our highest profit-generating businesses, mostly because there is close to no operational costs associated with this brand".

In addition to the T45 pipeburster operating within Gothenburg, the company decided to invest in the

larger T125 pipeburster in 2005. Due to the scale of work mounting up, the workgroup added the mid-range machine, T85 pipeburster 2 years later.

The three machines would cover the majority of the pipe replacement in Gothenburg, handle all operations ranking from just 40mm (2") existing pipes, up to Ø500 mm (20").

The many years of pipe-work has listed the Gothenburg Water Board as one of the most experienced state-owned companies in this sector. Projects carried out stretch from the lightest of PVC, over standard Cast Iron and Steel, to the toughest of Swedish Ductile Iron pipes.

The company works with 6 teams, operating the machines in shifts. All teams are highly professional and have extensive experience in static pipebursting.

In January 2010 Gothenburg Waterboard re-invested in additional equipment. Adding a T175 pipeburster from Scandinavian No-Dig Centre to the existing machine programme, this enabled the company to take on even bigger and more complicated projects.

The first of these is described below.

Location;

Gothenburg – Sweden.

Nya Allén (Gothenburg City Centre) approx. 3 km. reaching from Ullevi stadium to downtown Gothenburg. This boulevard spreads over a total of 6 car lanes and is a major carriageway for the traffic in the city centre. Thousands of cars use this busy street every day.

One of the city's transmission water lines runs directly under the "Nya Allén" boulevard. In approx. 2.5 – 3.0 meters depth. This 120 years old cast iron-pipe line stretches the entire 3000 meters from one end to the other.

The project has been on the table for quite some time, but not until the water board announced its latest purchase of the T175 machine, was it decided to commence the project. Initially 1000 meters was to be replaced with a new HDPE Ø560, as soon as possible. If the city approved of the quality of this work, an additional 2000 meters would be released.

The first part of these 1000 meters went along the middle of the Nya Allén, where the traffic is worst. On a snowy February morning this year, the T175 team was set to replace the first 130 meters.

The T175 pipeburster, with its 175 metric tons pull back power (193 us short tons), is built to replace existing pipes up to Ø710 mm. With a footprint of 1.8 meters in length and 0.7 meters in width, this unit takes up a minimum of space in these congested city areas.

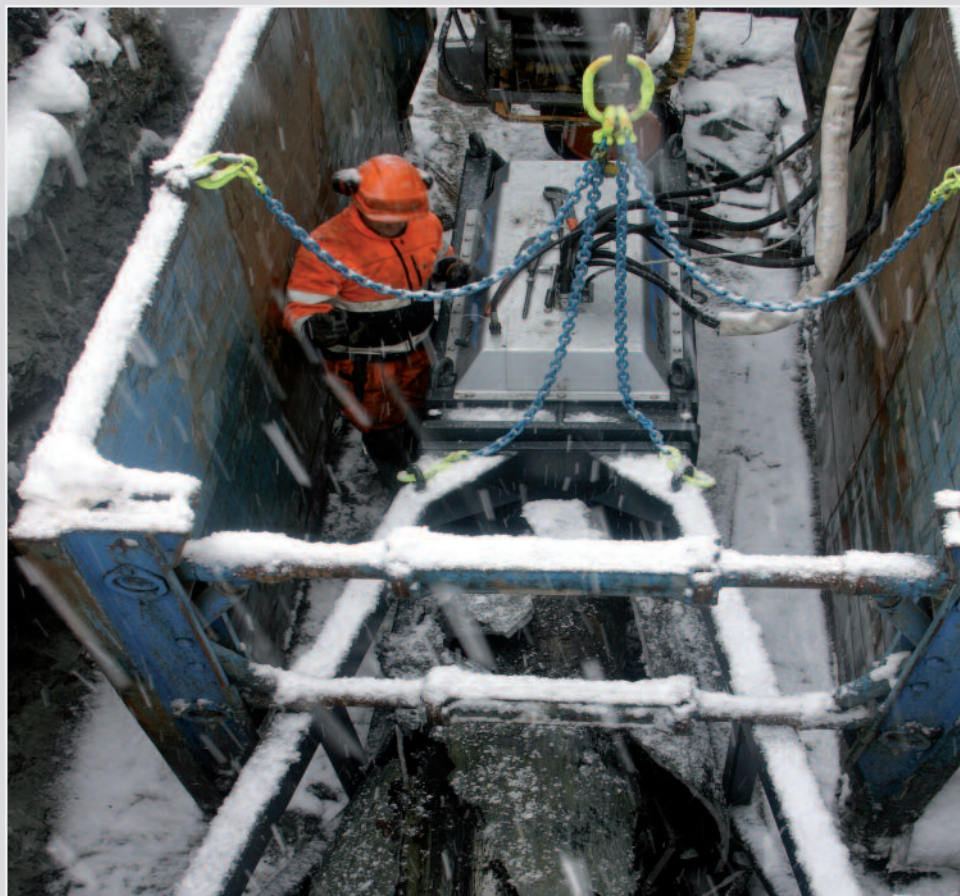
One of the major reasons for the Water board to choose this unit was the unique steel rod safety system using "The Positive Grip". This unique jaw-system prevents the steel rods from flying back out of the pulling unit, in case of a material failure during pulling-operation.

With its latest investment of hardware and the now full range of static pipebursting machinery, the Gothenburg Water Board has taken another important step towards being well-equipped for the new decade.

Setting the standard as high as possible when it comes to modern equipment and safety, Gothenburg Water Board becomes a front-runner in the use of Trenchless Equipment, and is considered one of the most experienced users of static pipebursting equipment.

Free DVD

In this magazine, you will find a DVD enclosed, featuring the latest material from the projects completed by Gothenburg Water Board, as well as information on the complete range of Static Pipebursting machinery from Scandinavian No-Dig Centre - Denmark. The company supplies static pipebursting machinery with a pulling capacity from 45 metric tons up to 400 metric tons.



SCANDINAVIAN NO-DIG CENTRE

Asian adventure



When it comes to finding your first job from university, ads in the back of the paper stating 'would suit first jobber' usually mean a role as an office junior or lowly mailroom assistant. Not for Sam Evans, whose first job has seen him relocate to Hong Kong to work on the city's Harbour Area Treatment Scheme project with Leighton Asia.

"I've only been on the project for about five months, but I've been through the initial stages of what the project entails and now I feel like I'm a useful part of the team and I'm contributing," says Sam, who's working as a site engineer and geologist on Stage 2A of the project. "I have a bit to do with various different aspects of the project including shaft sinking, which is quite interesting. Also I'm working on designing the layout of the construction adits with our Norwegian JV partner LNS,

so I'm getting a few different experiences."

A typical working day for Sam is varied and starts at 8am with checking documents relating to work carried out the day prior. "I have to make sure that all the work that has gone on has been accounted for before sending that information off to our independent checking engineers for confirmation," he says. Then after an hour or two out on site, taking a look at the work that's ongoing and dealing with any samples that need to be taken and logged, he usually spends the afternoon in the office. "After lunch, I spend a couple of hours working on the tunnel development plans to make sure they're on track and then maybe have a look at the work programmes to see how the timescale all fits together. It's quite a broad experience throughout the day and there are also some odd jobs that come up every now and again."

Sam only graduated from his Applied Geology course at Camborne School of Mines last June, which means the move east has lacked the sense of upheaval usually associated with starting a new job abroad. Located in Falmouth, Cornwall, Camborne is a small but specialised college that focuses on mining engineering, geology and also offers a degree in renewable energy. Leighton approached the institution, previously an independent college but now part of the University of Exeter, to see if they had any graduates suitable for the job.

"As it's my first job it's been quite easy to get used to as I haven't had to change too much," he explains. "But Hong Kong is definitely a bit of a culture shock, even though it's quite an easy place to get used to. I've had to learn a bit of Cantonese to speak on site, which has been funny."

Sam finds the different technologies used in the project interesting, and is thriving working in a foreign land. "I initially envisaged I would stay here for about two years, as I thought that would be enough time on my project for me to get experience in shaft sinking and tunnelling, but I can definitely see myself staying for longer," he says. "Every ex-pat I speak to says they came out for an 18-month or two year contract and ended up staying for fifteen years and counting. So I think it's very easy to place to get stuck in!"

Should he tire of Hong Kong, Sam is

confident that he could potentially be involved with one of Leighton's other projects in the region. "Working for such a big international company means they have projects all over Asia, so there is definite scope to move there with the company. And Leighton Holdings is a massive company in Australia so there's a whole other aspect of it as well. I can see me being away from England for a few years!"

The social side of the city has also enthralled Sam, who recently turned 22. "The company pays for a flat which I share with two other young lads from the UK. It's on Hong Kong island, in the middle of a really busy shopping, restaurant and bar district, so we have everything on our doorstep, there are lots of bars nearby." With such an inviting environment on his doorstep, perhaps another benefit of the flat is that it's only a 20 minute commute to work.

But there is more to Hong Kong than its glittering nightlife, as Sam has also discovered. "We've had the chance to explore as well. The great thing about Hong Kong is not that it's just a big city, it's got nice beaches and countryside. You can go for walks out in the hills or spend a day on the beach when the weather's nice. It's very nice, very easy to get used to."

Being so busy in and out of work means that Sam has not suffered from homesickness. "Other than the friends I left behind, I don't miss the UK too much," he says. And there's been no need to crave British staples such as Marmite due to well stocked supermarkets. "The great thing about Hong Kong is that you can get everything from home here. You might pay twice what you would at home but you can always get hold of it if you need it. The only thing I can't get is roast potatoes, they don't seem to have roast potatoes here!"

However, Sam won't have to wait too long for some roast potatoes as he'll be using the annual complimentary return flight Leighton assigns all its overseas staff to visit the family home, near Reading, this Easter. "After six months away, I'm looking forward to it now." Will he be bringing a bag of Aunt Bessie's back with him? "Maybe, or maybe I'll just eat loads when I'm there!" he laughs. ■

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Thomas R. Kuesel

Thomas R. Kuesel, a recognized authority on tunnel and bridge engineering and former partner at Parsons Brinckerhoff (PB), died on February 17. He was 83 and lived in Connecticut.

During a 43-year career with PB, Thomas contributed to the design of more than 130 bridges and more than 140 tunnels in 36 states and on six continents.

Among projects on which Thomas served as PB's principal-in-charge, project manager or project engineer were the Newport/Pell Bridge in Rhode Island; the original Talmadge Bridge in Georgia; the Fort McHenry Tunnel in Maryland; the second Hampton Roads Bridge-Tunnel in Virginia; and the Cumberland Gap Tunnel in Tennessee and Kentucky.

For the North American Air Defense Command Center (Norad) outside Colorado Springs, Thomas designed a unique structural support system for deep underground chambers that used intersecting spherical and cylindrical surfaces to mutually reinforce and support

each other, and to transfer load-bearing from weak to solid rock. For Atlanta's Metropolitan Atlanta Rapid Transit Authority (Marta) system, Thomas led the design of an innovative method of mining the Peachtree Center subway station from below ground, using the rock itself as a structural reinforcement.

From 1963 to 1967, Thomas was assistant manager of engineering for a joint venture of PB, Tudor and Bechtel on the Bay Area Rapid Transit District (Bart). In that position, he directed the design of 32km of subways, 40km of aerial structures, two hard-rock tunnels and a 5.8-km immersed tube tunnel under San Francisco Bay.

Thomas was a graduate of Yale University with bachelor's and master's degrees in civil engineering. He joined PB in 1947 as a junior bridge engineer. He was named partner in 1968 and in 1984 became Chairman of the Board of Parsons Brinckerhoff Quade & Douglas, then PB's U.S. transportation engineering arm. He retired in 1990 to become a consultant.



Thomas was co-editor of the Tunnel Engineering Handbook, first published in 1982, a comprehensive guide to the design and construction of virtually every type of tunnel. He published more than 60 technical articles on tunnels, structures, and contracting practices and was a registered professional engineer in 21 states.

Thomas was elected to the National Academy of Engineering in 1977. He was an honorary member of the American Underground Construction Association. ■



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Going off the rails

Booming activity in the Asia Pacific region is being fuelled in part by the demand for railways. Jon Young looks at activity in the region

Globally the tunnelling industry has battled through the stormy recession with some success. It has fared better than many other sectors of construction. Early hopes that construction would escape unscathed, or even benefit from a government investment drive, were short lived. The construction boom of the past decade slowed and companies pulled back to their head offices and batted down the hatches to ride out the rough times.

But for some parts of the world, the much longed for green shoots of growth are clearly visible and some initiatives are even beginning to flower. Tunnelling firms in the Asia Pacific region are enjoying a good level of work with real prospects of major tunnelling works over the coming years.

In a Tunnelling Industry Outlook survey by T&T publisher World Market Intelligence, nearly all respondents expected positive growth in the Asia Pacific region. The only other region to see such high growth forecasts was the Asian Subcontinent.

Growing workload

There has been a lot of focus on China over the past year as many companies make moves to capitalise on the cheap labour and the continued growth in the country. US machine manufacturer Robbins used its

China factory to build the heavy steel parts for the TBM digging the Emisor Oriente tunnel on the other side of the world in Mexico. The lower labour and steel cost made China the cheaper option despite the added shipping cost.

But Robbins and other manufacturers are not only using China to supply western projects. China is home to some major tunnelling projects of its own. The Jinping hydropower project near Chengdu is using two giant 12.4m Robbins TBMs and a Herrenknecht TBM. While in Shanghai, the finishing works are underway on the USD 1.5bn Yangtze River Tunnel.

Hong Kong stands out as a hub of tunnelling activity in China. Hong Kong Tunnelling Society chairman David Salisbury told T&T that tunnelling activity has steadily increased in the region over the past year and was set to boom over the next two years.

The railway sector in Hong Kong is following a global growth trend in the rail tunnels sector. Some 87 per cent of respondents to the tunnelling survey expected growth in rail tunnel business. Hong Kong is a great demonstration of this growth. The map (left) shows the five expansion projects for the Mass Transit Rail (MTR) lines in Hong Kong and it also shows the New Territories section of China's

Express Rail Link. Together the projects have a total of 22 major tunnelling contracts.

The survey credits railway boom to the economic success of the region: "Since these regions have acquired considerable economic strength, huge investments are being made to improve infrastructure. This is done because infrastructure will play a pivotal role in attracting foreign investments and in increasing business activities in these regions. Thus, various tunneling schemes are being implemented for both regional and national traffic routes."

The railway tunnel boom is also being felt elsewhere in the region such as Singapore, which is a second hub of tunnelling activity in the region. The Circle Line being completed this year for the Land Transport Authority has generated some USD 6.7bn of tunnelling work.

Ho Chi Min City, Vietnam also joins the railway tunnelling boom as early works have begun on a six line metro scheme being completed using cut and cover and TBM bored tunnels (see feature, p39).

Railways are not the sole driver of growth in the region. Major water transfer schemes as populations relocate and drainage and sewerage schemes to cope with increasing populations in cities are all increasing the tunnelling workload in the region.

Some 79 per cent of survey respondents said water and sewerage projects would grow in number over the coming year. And most of the work is expected to be public sector funded. ■



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A 2-day ITACET tunnel training course will be offered on Friday May 14, 2010 and Saturday May 15, 2010, at the Vancouver Convention Centre. It is organized by ITACET Foundation and coordinated by Garry Stevenson. Numerous tunnelling related subjects and case histories will be offered and presented by industry-distinguished professionals. A certificate of participation will be provided for accreditation of any professional organizations.

Accommodation Deadline: April 1, 2010

A limited number of rooms have been reserved on behalf of participants in several hotels located in downtown Vancouver and in the vicinity of the Vancouver Convention Centre. You are reminded to reserve your accommodation early. May is a very busy time in Vancouver and it is strongly recommended to make hotel reservations as soon as possible.

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Kowloon's fight against flooding

Working at 4bar confinement pressure through mixed ground and on a tight schedule will test the tunnellers on the Lai Chi Kok drainage scheme. Jon Young reports

be the toughest obstacles on the Main Tunnel drive. Opting for a one TBM solution to bore both tunnels has created a tight schedule that will ultimately be the contractor's most challenging test.

The low-lying district of West Kowloon in Hong Kong is battling against frequent flooding during the wet summer months. The runoff from the hills that tower above the reclaimed waterfront district is overwhelming the drainage and overflowing into the streets. To protect West Kowloon from the hillside runoff, work has started on a drainage network that will catch the water in the hills and carry it under the district to the harbour.

Funded by the Drainage Services Department, six catchments will carry water via shafts and adits to the Lai Chi Kok Branch Tunnel. The 4.9m diameter Branch Tunnel feeds water 2.3km to a culvert and shaft that drop the water into the Main Tunnel. The 4.9m diameter Main Tunnel then guides the water a further 1.1km to the harbour via an inverted syphon. Australian

contractors Leighton – John Holland Joint Venture started boring the Branch Tunnel last month, the first major works for the project.

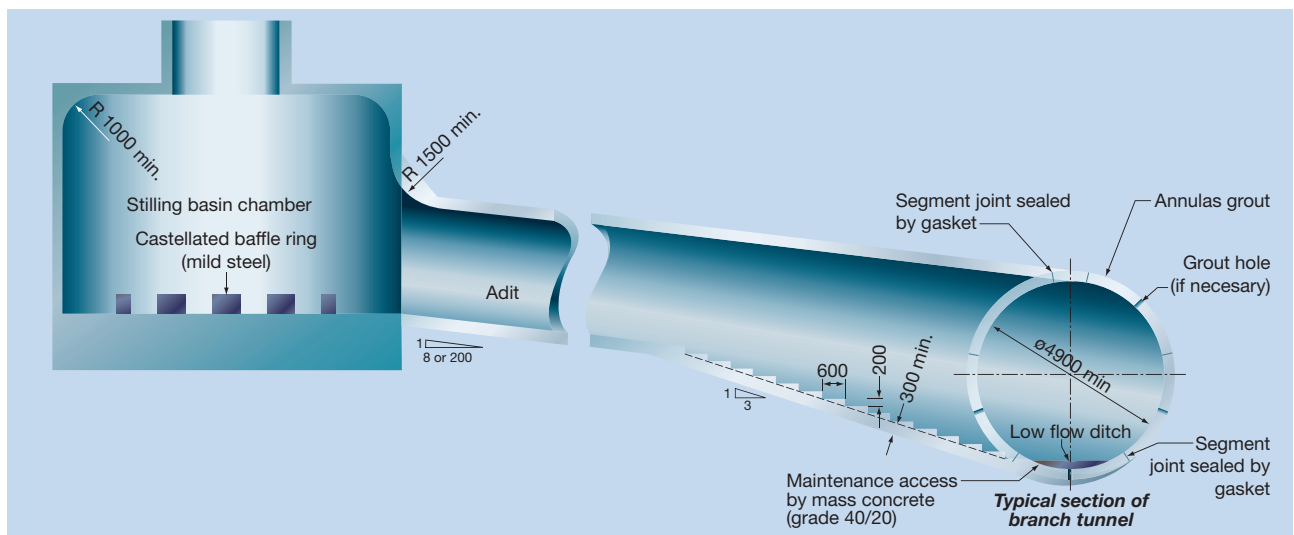
Very hard rock of up to 325UCS threatens the success of excavation on the Branch Tunnel, while mixed ground and working at 4bar confinement pressure will

Branch Tunnel launch

Before the Herrenknecht mixed shield TBM could begin excavating the granite, a launch chamber was needed to cut through the mixed ground of the hillside and create enough space for the machine's assembly. Leighton project



Right: The TBM onsite ready for launch last month; Below: A cross section through the adit and Branch Tunnel





Left: The front of the TBM is a squeeze with two man locks needed to speed maintenance works

Both the main and Branch Tunnels are driven as a one pass, so the precast segments are the final lining. There are 1880 rings to place for the Branch Tunnel and 928 for the Main Tunnel. The tunnel is sealed using the combined ethylene propylene diene monomer (EPDM) hydrophilic gasket from Phoenix, so the gasket is put on Nippon Hume's precast factory in Shenzhen and then the hydrophilic strip is inserted just before they go in the tunnel. Verman says, "Our maximum hydrostatic pressure is 80m or 8bar so these gaskets and the lining are designed for a 100m of pressure. On the Main Tunnel the hydrostatic pressure is just 42m."

Verman says the Branch Tunnel poses two main challenges: rock and schedule. The drive passes through two granites, the first 575m are in Shatin Granite, which is coarse grain. It then enters the Kowloon granite, which is a medium grain. The rock strength is expected to average 158UCS through the drive but with peaks of up to 325UCS. The TBM is armed with 17-inch (431.8-mm) cutter discs with a 19mm tip. As the same TBM is needed for the Main Tunnel, the operators are hoping for a 13m per day advance rate to complete the drive by August. To achieve this two crews will work in 10-hour shifts with four hours of maintenance six days a week. The machine will then be dismantled and withdrawn from the tunnel for reassembly and launch on the Main Tunnel in November.

Main Tunnel

The 1.1km Main Tunnel is in very different ground and will present the contractor with its own challenges. From the shaft the TBM will bore through granite but quickly the rock head dips down and the bore goes into mixed, highly jointed ground with large sections of soft ground with core stones. The contractor hopes to complete the Main Tunnel by July 2011. The bore will have a 0.1 per cent down gradient.

To cope with the changing geology the TBM will have 17-inch, 25mm-thick cutter discs. "The tip gives you less penetration per revolution but there is more meat on it so it is more impact resistant," says Verman.

The main drive is at 4bar confinement pressure, which throws new challenges at the contractor. Verman explains, the Hong Kong regulations were written mostly in the 1970's for the construction of the

manager Piers Verman explains, "The launch chamber is about 37m long, it is canopy tubes with lattice arch and shotcrete support. We drove the canopy tubes and then using a 12 tonne excavator pulled the face down as a heading and bench with a 5m stagger between the two and then shotcreted in 1.25m headings." The team then cast a concrete cradle with the rails in the bottom to push the shield though.

Verman adds, "The chamber was built so we could assemble a sufficient length of the TBM for launching." The 5.7m-diameter TBM was launched with the minimum gantries it could without having to use big umbilicals.

"At the end of the chamber we were aiming to get full face rock, in fact we've got grade 4 at the face, so it stands up and there is very little water. We did a little bit of pre excavating grouting but nothing major," says Verman. Some grouting was used in the canopy tubes to ensure that a road above was not undermined. A microfine cement from Tam was used to good affect. "It worked very well," says Verman, "with no water coming in through the roof. The ground in general was quite dry in that area. The face was always dry."

The 700 tonne mixshield TBM arrived on site in late December last year. Once

the shield was assembled it was edged forward to the face with the gantries constructed behind it. The first 22 rings were built as the shield was pushed into position for the launch. The universal rings are erected in a 5:1 configuration with five segments of 260mm thick, 1.25m wide and with an internal diameter of 4.9m, plus one keystone.

"The contract specified 60MPa concrete," explains Verman, "which is a little bit higher than we'd normally use, we'd usually use 50MPa, because the quality control for the higher strengths is a bit more difficult but so far all the test results are great, we have significantly higher strengths than the 60MPa."

For the first 22 rings the grout used to fill the void behind the tunnel segments was pumped through the segments but as the TBM bores through the granite the grout will be pumped through the tail skin. "We were grouting with the two-part grout. Part A is cement, bentonite, water and a stabiliser. It is pumped to the TBM from the mixing plant, some 2.3km when deepest in the bore. The part B is a sodium silicate about 80l per cubic metre. The silicate is injected into the part A about 900mm before it exits the tail skin so we adjust the gel time so its got time to clear the tail skin before setting."



Mass Transit Railway (MTR) tunnels, many of which were done as fully compressed air tunnels with bulkheads at the portal. Verman says the regulations have not kept up to date with modern TBM production so the limit is set at 50psi, which is 3.45bar.

“Our Main Tunnel requires that generally we have a confinement pressure of 4bar. If we have to go into the bottom of the machine to work on the crusher we’re at 4.2bar. So we’ve had to apply to the Labour Department for a dispensation from the regulations to operate at that higher pressure.”

When entering the pressurised front of the TBM for maintenance, workers are hindered by narcosis. People become much less efficient as the pressure gets higher and the nitrogen in their brain begins to inhibit their movements. Efficiency is further hindered by the longer decompression times.

“The decompression times under the French tables at this pressure are actually longer than the working time. So we get a point where team A goes in, team B then has a handover as team A are coming out

and team A decompress for longer than the working time of team B.”

To improve efficiency the contractor opted for a double man lock on the TBM. “We’ll have the first team go in and check the condition of the cutters. They’ll have to get their hand round the front to make sure they’re not flat. We’re only going to manage one cutter per team after that. We have allowed in our program that we will go past the four-hour maintenance period in the Main Tunnel,” says Verman.

To minimise maintenance requirements in the difficult ground the contractor is looking at various cutter disc options. “On a previous job we experienced damage due to corestones from the impact, the disc doesn’t wear, it breaks, and you’ve got to go in and replace it straight away,” says Verman.

“We’ve discussed mono blocks but they are expensive,” he adds. “But we have opted for pressurise compensating discs. With a traditional cutter they don’t pressurise the inside of it so as the pressure builds up on the outside the seals are having to resist more and more slurry pressure. On our cutters, there is a membrane in the centre of

the shaft, which then pressurises the oil in the disc so that the slurry pressure is equal to the oil pressure. This stops the slurry getting pushed into the cutter.”

Choice of TBM

Leighton-John Holland JV decided at tender stage that it wanted to go for a one TBM solution. This made the mixed ground, high-pressure Main Tunnel the primary driving criteria for the TBM design.

TBM specifications

Curve radius	200m
Working pressure	4.5bar
Bore diameter	5720mm
Weight (with tools)	58t
Disc cutters (1 ring)	31
Disc cutters (center)	4
Disc cutter diameter	432mm
Cutting knives	25
Type	hydraulic ring drive
Torque (nominal)	5547kNm
Breakaway torque	6934kNm
Maindrive diameter	3000m

Below: The 5.72m TBM at Herrenknecht’s factory in China





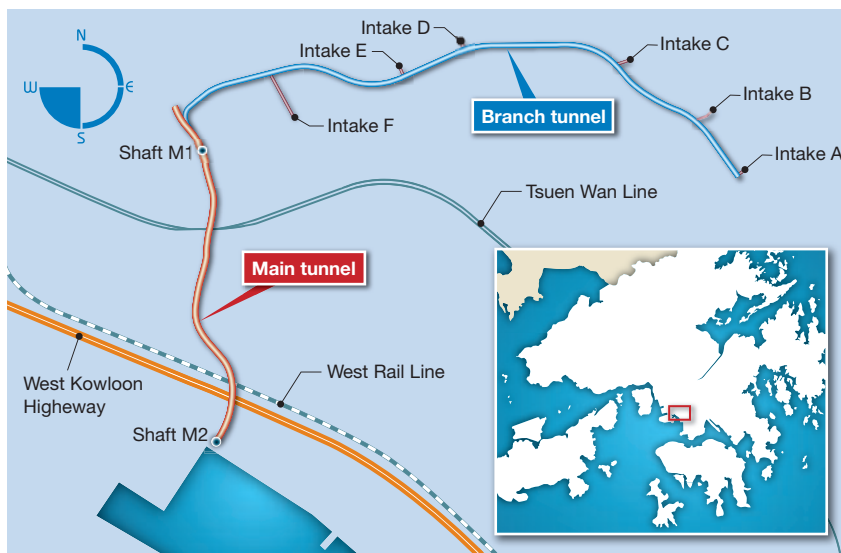
"We elected to go for a mixed shield on the Main Tunnel and as we only wanted to use a single machine for both drives, that dictated what we could do on the Branch Tunnel. The positive knock on effect for us was that using a closed face machine on the Branch Tunnel meant we didn't have to do pre excavation grouting to control water inflow, which took a significant amount of time out of the program. That gave us a one TBM solution that worked quite well," says Verman.

"We did look at dual mode machines, looking at using one TBM like an EPBM for the Main Tunnel that could be used in open mode for the Branch Tunnel but that came back to the pre excavation grouting again. And it was also quite a small machine to get the dual mode criteria," adds Verman.

However, the TBM also needed to be able to cope with the hard rock the contractor expects on the Branch Tunnel. "When considering the hard rock we discussed what would happen when we hit rock of 325MPa. The penetration rate in mm per revolution drops off quite dramatically. There is nothing we can really do with the cutters, we still maintain the 25 tonnes per cutter whether the rock is 150 or 325MPa. We can't apply more load or the cutters will fail, we just have to allow for those variations in penetration rate.

The slurry TBM is equipped with one slurry return pump. For the Branch Tunnel return side two booster pumps are needed in the tunnel. For the feed side there is one pump on the surface and one booster pump in the tunnel. On the Branch Tunnel there will be a total of five pumps in the slurry circuit. Verman adds, "On the surface

Below: The plan of the tunnel alignments



Above: Herrenknecht country manager Thorsten Gartner speaks with Leighton Contractors project manager Piers Verman in the pressurised chamber at the front of the TBM before launch

we have a separation plant by PSD. The circuit is running at 1000 cubic meters an hour to maintain enough velocity to keep the granite in suspension and minimise wear in the slurry pipes. The slurry is pumped back to the separation plant where we've got a primary screen, two secondary screens and then the hydrocyclones. The fine material is then processed through two centrifuges. Everything drops into a muck

bin where it is loaded by an excavator for disposal off site."

Adits

The shafts and adits for the intakes will be the final stage of the project to be completed. They will carry the water from the catchments into the Branch Tunnel. "Our adit shafts are all done from a top down approach, so we come down the shaft and then blast toward the tunnel, we are not constructing the adits from the tunnel because we don't do any raised boring," says Verman.

"We blast up to 5m short of the tunnel lining and then do drill and split and remove the segments from inside the tunnel. We then finish the connection works between the cast in situ lining of the adit and the precast lining of the tunnel."

There are six adits, A to F. A has the deepest shaft at 60m and F is the longest adit at 180m long. All the adits are 3m in diameter and as they approach the tunnel they increase to be the full 4.9m internal diameter. The roof of the adit projects through at a constant grade and the invert drops as you get to the tunnel.

The entire drainage project should be completed in May 2012 for functional testing and handed over to the client on 17 July 2012. ▀



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Hong Kong flood relief

The western bore from Cyberport on the Hong Kong West Drainage Tunnel is employing three construction methods to alleviate flooding in Hong Kong's business district. Managing these methods in tough ground is testing the engineers, Jon Young takes a look



Above: The tunnel alignment picks up intake adits in the hill side

Left: The western bore from Cyberport will breakthrough near the Aberdeen tunnel 6km along the route

In a bid to alleviate the flooding problems in northern Hong Kong Island work has begun on the Hong Kong West Drainage Tunnel (HKWDT) Scheme; awarded by the Drainage Services Department (DSD) to the Dragages-Nishimatsu Joint Venture.

Whilst the DSD has made improvements

and extensions to the aged systems, the improved drainage systems still fall short of current flood protection standards. They remain inadequate to deal with the flooding caused by heavy rainfall or typhoons.

Hong Kong experiences an average annual rainfall of some 2200mm, one of the highest among cities in the Pacific Rim. It is

located in a sub-tropical region and has a warm and humid oceanic climate making it vulnerable to heavy downpours and tropical cyclones.

With continuous urban development making the northern district of the island one of the most densely built areas of Hong Kong, the surface water run off has considerably increased in recent years; reducing the flood carrying capacity of the existing drainage systems and aggravating the flooding problems.

Affecting low lying areas including Sheung Wan, Central, Admiralty, Wan Chai and Causeway – the financial and business districts of Hong Kong – this therefore disrupts the economic activities and business operations leading to huge economic losses.

The project

The scope for the new HKWDT project involves construction of a new 11km long drainage tunnel deep in the ground in the



mid-levels of the island from Tai Hong to Pokfulam. The scheme will intercept and convey the storm water from the upper catchment areas directly into the sea near Cyberport.

The Dragages-Nishimatsu JV is responsible for constructing the tunnel in two sections. The first 4.5km long and 6.25m in diameter, will run from Tai Hong and under the Aberdeen tunnel.

The second, 6km long and 7.25m diameter, is bored from Cyberport to the

Aberdeen tunnel and is where the most difficult challenges will be faced.

Geology

Using two TBM's for the main tunnel construction excavation had reached 2.5km from the western portal at Cyberport last month. The beginning of the Western bore is in mixed ground. The drive hit grade 2-4 rock, after approximately 20m, says deputy construction manager for the Dragages – Nishimatsu JV Shinjiro Arimura. The rock has proved challenging to dig by TBM as it frequently changes strength and stability along the drive. Within one 10m section the rock could change from fractured to very hard. On the first 2.5km of the western drive the rock has reached strengths of up to 290UCS and according to samples taken from further along the route, the TBM is going to have to bore through rock exceeding 300UCS. The drive has so far successfully passed

Above: The western tunnel bore is permanently lined with 310mm thick precast segments shipped to site from Shenzhen, China

through two major faults.

In fractured rock the TBM is able to advance 40-50mm/min, says Arimura, and in hard rock this drops off to 0.25mm/min. The record for advance on the western bore is 18 rings in one day.

To cope with the geology, Arimura explains that a four hour maintenance period is needed each day to replace worn and broken 17 inch (431.8mm) cutter discs. Breakthrough is anticipated some 6.5km from the western portal.

Water logged

When the boring began from the western portal the drive quickly ran into water difficulties, which lasted for some 900m. More than 450l of water flowed through the probe holes every minute. To stem the

Who's who?

Client:	Drainage Services Department
Main contractor:	Dragages-Nishimatsu Joint Venture
Consulting engineers:	Ove Arup & Partners Hong Kong
TBM manufacturer:	Herrenknecht



flow the team used extensive pre excavation grouting. A probe hole was drilled 40m ahead of the machine and the inflow was checked. Some 11 grouting holes were then drilled through the sides of the tunnel at an angle of 5 degrees to the tunnel alignment.

The micro cement grout from Tam was injected to refusal at 80-100bar pressure. Some 50 hours of treatment was needed for every 30m of advance through the wet section. This considerably slowed progress. It took some five months to get through the 900m section, double the scheduled time of just two and a half months.

The project has so far used more than 1000 cubic meters of grout to manage water flows. Arimura explains that managing the water through pre grouting was a contractual requirement because of ground settlement fears.

The tunnel is being permanently lined with precast segments manufactured in Shenzhen, China, and shipped to site. On the western bore from Cyberport the segments are 310mm thick, 1.5m wide and have an internal diameter of 7.25m. On the eastern bore the segments are smaller at 283mm thick, 1.5m wide and 6.25m internal diameter.

To lessen hydrostatic pressure on the tunnel gaskets between segments have been left out to allow water to flow directly into the tunnel. Low cover sections, with an overburden of less than 50m, have gaskets because of settlement concerns.

Adits

The drive from Cyberport has 22 of the 32 adits planned for the entire tunnel. The adits link the main tunnel to intake shafts. Work on the first two adits had begun last week. For each adit, segments are broken out of five tunnel rings. The first 5-6m of the adits is then excavated using drill and split as Hong Kong regulations do not allow drill and blasting to be used that close to the tunnel.

Once past the drill and split section the tunnellers will start blasting to the shaft. Blasting is carried out once a day working, according to JV Plant Manager, Masanori Ishii, on up to 12 faces simultaneously. This includes initially, for example, two faces of the first adit, three faces of the second adit and three of the third. Most of the adits will be 2.59m wide and 2.25m high.

Drop shafts

A total of 34 intake shafts are to be excavated to intercept waterflow from existing drains or streams along the 11km route. Most will be constructed using the 'raise boring method' initially using a small

diameter pilot drill to bore down to the adit. At the bottom a larger reamer brought in along the adit is installed to the drill rod.

The reamer then bores upwards to the ground excavating the shaft along the way. All excavated material falls to the bottom for retrieval via the adit and is removed to the portal.

The finished drop shafts feature a mix of three diameter sizes – 1.5m, 1.8m, and 2.3m and a variety of depths varying from 17m to 170m at Tregunter Path.

Mucking out

The majority of the spoil being removed from the western portal is carried by an elevated conveyor supplied by Marti Technik. The conveyor carries the muck from the TBM to a barge at Cyberport. However, the tight space in the adit construction, coupled with the large volume of material that will be removed from the adit and shaft, has led the contractor to employ a second system.

A fleet of two 8 HR2-B Gia Häggloaders, three sets of Gia locomotives and nine shuttlecars are being used throughout excavation of the shafts. The Häggloaders, generally fitted with two digging arms to speed the mucking out process at the face, have been modified to include just one arm due to space constraints. The arm is also used

for scaling the blasted profile.

Using its built-in conveyor the Häggloader is able to continuously load the blasted spoil from the face into the offering loading capacities of up to 3 m³/h.

For the seven shorter adits on the western bore the contractor is utilising a skid loader to remove the spoil directly loading the shuttlecars in the main tunnel, in place of installing rails for the Häggloader.

The west drive is expected to be completed at the end of 2010 and it will take another year for the adits to be completed. In a 49-month contract, final completion of construction is scheduled for December 2011. Consulting engineers for the project, responsible for planning and design, is Ove Arup & Partners Hong Kong. ▀

Right: A forward looking view on the right side of the TBM

Below: A precast segment is removed from the tunnel wall at the start of construction on the second western adit





1



2

- 1 External belt at the Bibra tunnel.
- 2 Stacker conveyor mounted on tripper.

Efficient conveyor belts for long railway tunnels

The excavated waste material – approx. 1,100,000 m³ – of the 2 x 6,466 m Bibra rail tunnel on the Erfurt-Leipzig/Halle section of the Nuremberg-Berlin high-speed line is removed from the tunnel by Marti Technik's conveyor belts and then transported beyond the tunnel entrances to the dump storage area. The conveyors have capacity for 500 tonnes/hour.

The three conveying systems are composed of a total of eight belt units:

- System 1, east portal consists of 355 kW conveyors in tunnel, 110 kW link conveyor, 45 kW dump site conveyors including tripper, ended by a 11 kW reversible stacker conveyor.
- System 2, west portal includes 250 kW conveyors in tunnel, 45 kW dump site conveyors including tripper, ended by a 11 kW stacker conveyor.
- System 3 adit window consists of 250 kW conveyors in tunnel and 110 kW link conveyor.

The total installed power is approx 1,000 kW. The belt widths equal 800 mm and 1,000 mm.

The tunnel conveyor is suspended to the tunnel vault by chains on two sides. The tunnel conveyors are fed by crushers in the tunnel. The conveyor is extended by jump of 450 metres to each connection tunnels.

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52.2 mm

The length of a Monarch caterpillar „Danaus plexippus“ after 10 days and the vertical offset of the laser from the line of site of the theodolite used in VMT's tunnel guidance systems.



Planning a metro in Ho Chi Minh City



Ho Chi Minh City's seven million population is not served by a transit system

Planning for Line 2 of Ho Chi Minh City metro reveals it will hold some major challenges for tunnel engineers. Emma Gritt reports

It may come as a surprise to learn that Ho Chi Minh City does not have a formal public transit system. However, plans are currently underway for huge infrastructure works that will give the city's population of over seven million a six line metro system and improved bus links.

Following the approval of a Transport Network Master plan for Ho Chi Minh City by the Prime Minister Vo Van Kiet in January 2007, city officials hope to increase the modal share of travel in the city by public transport to 40-50 per cent by 2025. The development of an urban rail network is

seen as the backbone to achieve this aim, and the transport plan features a network comprised of six Mass Rapid Transit (MRT) lines totalling 109km in length, as well as two monorail routes, and a tramway. Upon completion, the network will be owned by a committee created by Ho Chi Minh city, the Management Authority for Urban Rail.

Line 2

The greatest challenge for tunnellers is going to be faced on Line 2 of the scheme,



The MRT network

The other lines in the Ho Chi Minh metro project will also rely heavily on tunneling. Chris Burley of MVA Asia explains, "The other lines will also use TBMs. Each line will be built as and when funding can be arranged. Lines 1 and 2 are at the preconstruction stage at the moment with other lines at the planning stage. Line 1 tenders have already gone out."

Line 1 is 19.7km long and consists of a 2.6km-long underground section and a 17.1km elevated section. Line 1 will connect Ben Thanh Market in the central area to the amusement park at Suoi Tien in District 9. The line goes underground from Station 1 at Quach Thi Trang Roundabout area in Ben Thanh Market. It consists of two horizontally aligned two tunnels. After Station 3 at Ba Son the line shifts from underground to elevated. The underground section has a total of three underground stations. Line 1 also consists of a crossing at Saigon River.

where the majority of the works are underground. MVA Asia was appointed as consultants by the Asian Development Bank on Line 2 of the ambitious project. Chris Burley of MVA explains, "We're consultants working for Asian Development Bank who are the major donor for the line project. We have been working on the project in preparation for the tender process. It's still at the feasibility and

planning stage at the moment, but if they can close the agreement with the major lenders within the next few months which is what they're planning to do, we will probably be inviting bids early next year."

The initial 10 or 11km phase of Line 2 has a current estimated worth of USD 1.2bn, and its international tenders will be put out early next year with construction starting a year later in 2012. It will run north west from the city centre, starting just south of Ben Thanh, continuing in a north-westerly direction along Cach Mang Thang Tam and Truong Chinh before ending at Tham Luong, where a spur of about 1.1km will connect the line to the depot. In a future phase, it is planned that the 12.26km line will extend to An Suong in the north, and across the river to Thu Thiem and beyond in the east. Most of the line from Ben Thanh to Truong Chinh (around 9.6km) is underground, to suit the high density urban developed areas. The northern part of the line (around 1.6km) is elevated, on the median of Truong Chinh.

Twin single-track bored tunnels are proposed for the underground alignment (with cut and cover at stations). The use of cut and cover tunnel method was considered, but was rejected since it would have significant resettlement impacts along the narrow streets.

The use of a single larger (double-track)

bored tunnel was also considered, but whilst costs would be similar to the single-track tunnels, the larger single tunnel would require deeper stations, would need to provide additional safety exits, and would increase the settlement risk over the tunnel.

"They'll be using TBMs to bore the two 6.6m diameter twin tunnels, and currently we envisage slurry shield TBMs in the detailed design," says Burley. "All the stations will be cut and cover with deep diaphragm walls. And when it gets to about 8km out of the city centre it becomes elevated. These methods were opted as the streets are very narrow it would be almost impossible to build by cut and cover, and very expensive, so the TBM is the best option."

Civil works for this line include 6.97km of underground tunnel section (a total of 13.93km of bored tunnel), 2.5km of viaducts, a section of 136m open tunnel and a 222m section of cut and cover tunnel. Nine underground stations and one elevated station, 18 emergency and/or dewatering cross-passages and one rear garage at Ben Thanh will also be constructed.

Alignment

The tunnel's proposed alignment is based on findings from a feasibility study carried out by German consultants Tetra Tech in 2003, and updated in 2005. The study considered a number of options for horizontal alignment of the line, as well as different arrangements for underground and elevated sections. It was decided that the general route of Line 2 will follow the city roads of Duong Cach Mang Thang Tam and Duong Truong Chinh, meaning there is little scope for alternative horizontal alignments.

"The tunnel alignment was chosen in an earlier planning study conducted by the Vietnamese where they defined the main corridors for public transport in the city. And out of those corridors, these were selected as potential MRT corridors, and the Line 2 corridor, is, as the name implies, probably one of the top two in terms of catchment," says Burley.

The horizontal alignment is quite constrained due to locations of the stations within the narrow streets typical to the area, and the need to avoid building foundations. The adopted minimum radius for general track in open air or tunnel is 300m, reduced in exceptional cases to 250m. In stations straight alignment has been adopted at this stage, but this may



Left: A TBM driven tunnel has been chosen to lessen settlement risk as it passes under the congested city



Right, top: Cut and cover tunnels were ruled to minimise disruption during construction

Right, bottom: The planned Line 2 route

be reduced to minimum radius of 1,500m, exceptionally 1,000m subject to detailed design. In depot and access areas the minimum radius is 160m, with exceptional reduction depending on rolling stock.

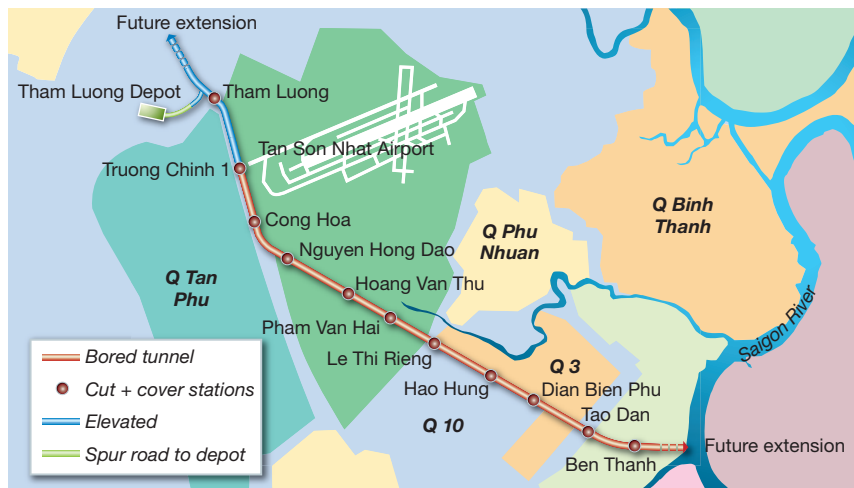
For passenger convenience, underground stations need to be shallow. However, geological analysis revealed that soil conditions for optimum tunnel boring and minimum settlement risk are at deeper levels, leading to a requirement for steep gradients between stations and tunnels to optimise design. The future need for the line to cross beneath the Saigon River also requires fairly steep gradients. A maximum gradient of 5 per cent has been adopted for the design, with gradient on one rail incant sections always less than 6 per cent and the minimum slope set at 0.2 per cent for drainage purposes. Vertical transition curves are parabolic at minimum radius 1,500m, exceptionally reduced to 1,250m. Overlap of horizontal transition curves, and vertical transition curves, is avoided wherever possible.

Line 2 will intersect with Metro Line 1 at Ben Thanh. Whilst the interchange will be subject to a separate study, it was assumed in Tetwet's feasibility study that Line 2 will pass beneath Line 1, and therefore the alignment is fairly deep at almost 30m below ground. Due to the short distance, and in order to avoid building foundations, the line remains deep to Tao Dan station, which is 19.8m below ground. A minimum radius of 250m is also required on this section to avoid building foundations.

The line remains underground on Truong Chinh past the end of the Tan Son Nhat airport runways, and then surfaces through an open cut transition area of around 230m just beyond Truong Chinh 1 station. The line runs on viaduct along the centre of Truong Chinh until it terminates just beyond the spur connection to the Tham Luong depot. Ground levels along the route of the alignment are fairly flat, as is typical of most of the urban area of Ho Chi Minh City. Levels are generally around +3m to +4m, with a low of +2.2m near Ben Thanh, and a high of +5.5m.

Geology

Ho Chi Minh City is situated over a thick accumulation of quaternary loose sediment layers, overlying layers of stiff clays and dense sands. This results largely



from the accumulation of particles carried and deposited by the Saigon River. It was observed in initial investigations that the constitution of soils in Ho Chi Minh City varies considerably depending on their vertical and lateral distribution. Water level is usually 1- 3m below ground level but the level may vary with different factors such as tide. Another aquifer lies in the sandy clay layer 40m below ground level.

"There's no rock, it's sandy clay. I think the construction methods are established for this sort of soil condition. There is water down there but the diaphragm walls will have to be pretty deep but I think TBM tunnelling is tried and tested for this kind of ground," adds Burley.

MVA's report noted that the overall distribution of the geotechnical units along the Line 2 tunnel alignment is well equipped to document the first 40m below ground level yet almost no data is available at a level deeper than this. Additional boreholes,

reaching a depth of more than 50m are needed, in particular at the station locations, to clarify the position of the boundary between the clay and sand layers, and on the aerial sections in order to precisely determine the level of foundations of the viaduct.

Another key challenge that this project faces is the attitude of the city's residents. Here, private vehicle use is the norm, leading to heavily congested and polluted streets. "I don't think we've reached a stage of design challenge yet," says Burley. "But I think a challenge will be disruption caused during construction as it really does go through a very congested area of the city. People are beginning to appreciate that as well as physically building this thing, there has to be a lot of support and legislation to make sure people use it when it is completed."

The tenders for Line 2 will be published in early 2011 and construction is expected to start in early 2012. ■

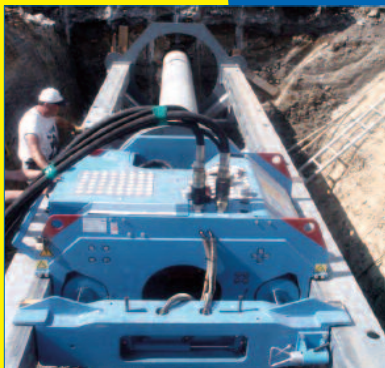


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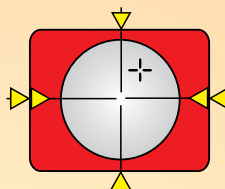
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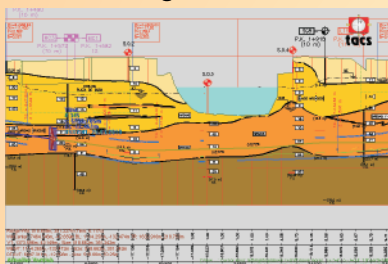
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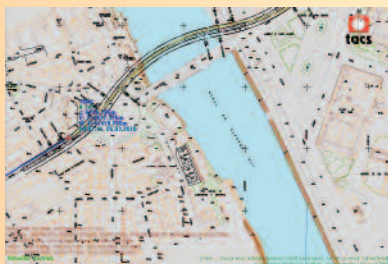


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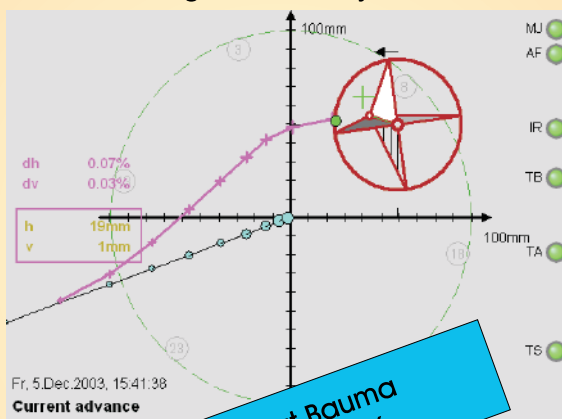
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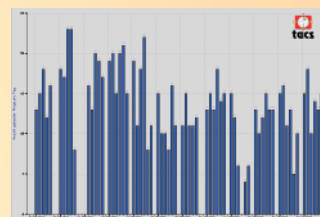
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Flexible friends at the face

When considering potential tunnel excavation methods, the discussion is usually between TBMs and drill-and-blast, yet many tunnels are dug within much more flexible methodology. Direct excavation of a stable open face, where possible, offers operational flexibility, the ability to deal with varying strata, and economy, even if the potential high progress of full-face methods may have to be sacrificed. Maurice Jones checks on the current means of excavation and the trends in their use.

Whatever the means of tunnel excavation, the more flexible it can be, whilst performing at the required rates, the more valuable it is. Equipment that can be mounted on mobile carriers and directed where excavation is required obviously has potential flexibility for quick transfer between working faces and within the face. Flexibility also extends to the section profile being excavated since there is no restriction on shape or width, within the maximum working height of the equipment. The method allows for the construction of horseshoe, oval or any required tunnel shape, and partial sections such as within the Sequential Excavation Method (SEM) and perhaps NATM.

It can also help if the carriers can be of compact dimensions so that they can fit in a small drive or in partial excavation of a larger face. Thus conventional hydraulic excavators, hydraulic breakers, roadheaders and rotary cutting head attachments can all be used for economical tunnelling on short drives, in smaller sections or within partial face methods.

Diggers

Conventional earthmoving plant has long been used to excavate large-section faces in soft-to-medium but stable ground. Their use can be extended if some form of ground improvement has been carried out before excavation.

In recent years contractors and manufacturers realised that more compact excavators could be used more safely in tunnels with smaller dimensions if a number of modifications were carried out.

Although specialist diggers were available, Caterpillar was the first to adapt standard surface-use excavators to the more demanding conditions in tunnels. Other major manufacturers such as

Liebherr have followed suit.

Terex, which now owns specialist tunnelling equipment manufacturer ITC, not only offers ITC breaker-equipped loaders, but also mini-excavators adapted to tunnel use.

Depending on the nature of the face, conventional face shovel configurations can be used, but different types of backhoes are more usual. For face work the backhoe has an improved digging action when used inverted and is equipped with special teeth to attack the face. A further possible design improvement is for the backhoe to be mounted on a rotary adaptor so that it can be turned through up to 180 degrees in either direction. This allows the excavator to dig around hard inclusions.

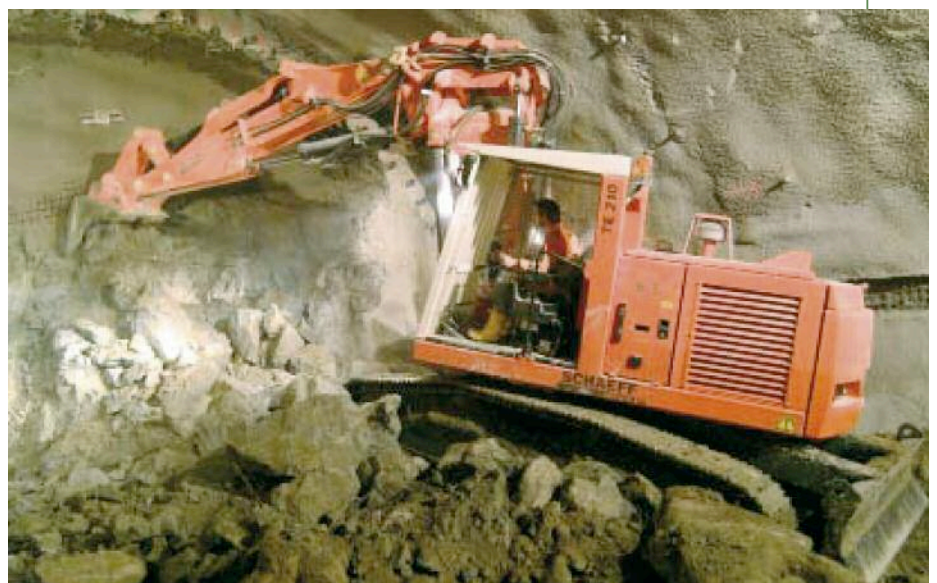
Tunnel excavators in the Terex-ITC range are available in four sizes with operating weights of 18-48t. The modular design of the basic equipment and working tools can be adapted to various tunnel sections and geological conditions. Suitable tool attachments may include rippers, backhoes, face shovels, hydraulic milling cutterheads (see below) and patented

hydraulic hammer and scoop combinations. Both diesel and electric drives are available with ratings from 55kW to 165kW, using the diesel for tramping and the electric for pollution-free operation at the face. An integral conveyor carries spoil from the loader to the back of the machine for transfer to main transport. The range of tunnel sections that can be excavated go from 8-25m² for the ITC 120 to 18-60m² for the ITC 320.

More conventional, but compact, hydraulic excavators for tunnelling are in the Terex range. This short-tail unit can be used in narrow sections due to its small 'footprint' when slewing. It has a 165-kW, exhaust-optimised diesel drive and can be applied to tunnel sections of 18-45m². Options include a 132-kW electric drive with cable reel.

Breakers

Specially adapted hydraulic breakers have been used for many years in mining and in hard-rock drill-and-blast tunnelling for improved safety by removing loose rocks from the tunnel crown and face to prevent



Right: A specialised compact tunnelling excavator, the Terex TE210

injury from falls and spalling.

More powerful and reliable designs of breaker have made their use practical for main excavation in some cases, but especially for short drives such as access passages and cross-cuts. On the ITC range they can assist in the main loading operation as well as scaling.

Other breakers come from the medium-to-high end of ranges of broad-range manufacturers such as Atlas Copco (formerly Krupp), Sandvik (formerly Rammer), Indeco and Rammit.

Roadheaders

Crawler-chassis-mounted roadheaders were first developed as a form of continuous miner for driving development tunnels in soft-to-medium rock mining. These were too weak for most civils tunnelling, but more powerful models were gradually developed.

Advocates of roadheaders claim that the method is safer than drill-and-blast in harder rock, and produces an accurate profile without undue disturbance of the surrounding rock. Together with much lower levels of vibration, these are the reasons that roadheaders are particularly favoured in much urban rock tunnelling.

Unlike some other methods of direct or partial tunnel excavation, progress rates can be impressive. Aker Wirth claims that roadheaders usually have a higher advance rate compared to drill and blast.

In many areas the name of Dosco is synonymous with 'roadheader'. The company's range has continued to increase in size and weight to enable the excavation of harder rock. The crawler carrier can also be used for other functions since Dosco can mount on-board rock drills for roof and sidewall drilling for rockbolting, probing the face, dewatering, grouting and spiling. Dust extraction units can be fitted to all Dosco machines to improve the working atmosphere. Operator cabs are dust filtered

and can be fitted with air conditioning.

As with other main tunnelling operations, roadheader control and monitoring is becoming easier with the use of electronics, and Dosco is no exception. Dosco engineering manager Alan Owens explained that the operator screen can display both the tunnel profile and cutterhead position. It can also interface with proprietary profile guidance equipment. The same screen also provides a display for machine fault diagnosis and to display feeds from surveillance cameras.

Dosco roadheaders have on-board diesel-drive power packs for tramping between work positions without having the normal electric power cable connected. During operation the cut rock can be discharged via a swivelled belt conveyor or an articulating scraper conveyor.

Whilst the general tendency has been to increase power and weight in roadheaders, Dosco's latest addition to the range is The LD2000, which has been specifically designed to operate in low drives of 1.8m height.

Dosco was one of the first to supply the boom cutters normally mounted on crawler carriers for use in tunnelling shields. These Dosco 'Boom-in-Shield' machines now incorporate a facility to set the maximum pressure for each thrust ram to facilitate machine steering, and also to automatically prevent carrier sledge roll during operation.

Well known for the design and production of tunnelling equipment for arduous conditions, Wirth, now part of Aker Solutions, offers three main models of roadheader from the former Paurat range.

Contractor OOO Tonneldorstroy (TDS) has just placed an order for a Wirth type T3.20 heavy-duty roadheader for infrastructure improvements in the city of Sochi, Russia, in preparation for the Winter Olympic Games in 2014. A new main road is being constructed through the centre of the city, including at least 15 tunnels. Wirth

roadheaders have also been used for tunnels on Sochi's new by-pass road, some tunnels of which are already complete. Three of four Wirth roadheaders were operated by TDS. The T3.20 is designed for tunnelling in medium-to-hard rock of up to 150MPa UCS, using 300kW of installed power in a 120-t unit.

The tunnel lengths are relatively short, at less than 3km each and sometimes only a few hundred metres. The short set-up time for roadheader is therefore ideal, taking under two weeks in this case.

North America

Despite introducing continuous miners for mining production, the use of related roadheaders for civils applications in North America had, until recently, not been as advanced as it has in Europe and the western Pacific.

Willy Kogelmann, founder and president of the Alpine group, holds claim to being the first to introduce roadheaders to North America in 1968, but the company's machines are now on sites worldwide. These include the Alpine Multi-Tool Miner (MTM) and cutterheads for mounting on other equipment, as well as full roadheaders. Alpine roadheaders are available with transverse or longitudinal/axial cutterheads that are interchangeable in the field.

Also based in North America, Antraquip manufactures a range of four self-propelled, high-power, AQM roadheaders. They go from 13 to 55t in weight with total power ratings from 60/132 to 350kW, giving cutter power ratings from 30/60 to 200kW.

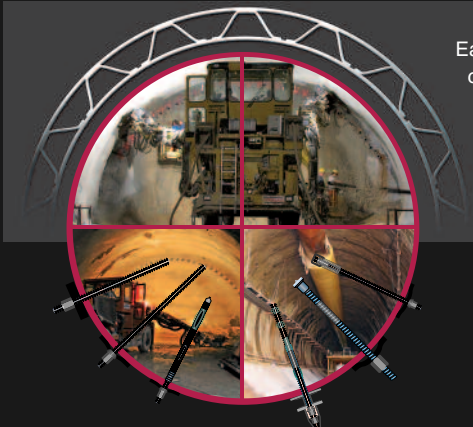
Antraquip sales Director, Peter Mitterdorfer, has reported on the use of roadheaders in the underground construction projects at Washington Dulles Airport where the use of roadheaders indicate the increased acceptance of the method in North America. This went in parallel with the adoption of NATM for the Pedestrian Walkback drive, constructed by Kiewit. The contractor used a 60-5 AM75-M roadheader for most of the excavation. Similarly Kiewit used an AM75-M roadheader for NATM construction of the West Utility Tunnel, following a rebuild by Antraquip. The average advance achieved by this 270-hp (201 kW) machine was 8-10 ft (2.4-3.0m) per day in material of 15 000 lbf/in² UCS (102 MPa).

When the Clark/Shea joint venture won the contract for the West APM (people mover) tunnels and stations, the Clark subsidiary



Left: An AM75 roadheader rebuilt by Antraquip for work on the Washington Dulles Airport West APM tunnel

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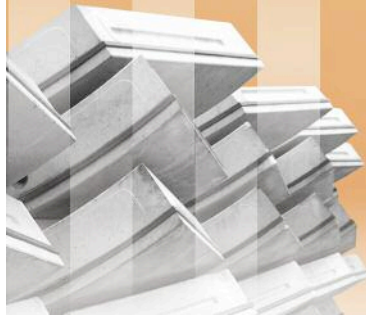
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Atkinson Construction, with its extensive experience of NATM, again chose roadheader excavation in sections not constructed by cut and cover. Antraquip supplied two rebuilt and custom-fitted AM75-M roadheaders for the top heading and one rebuilt AM50-M for invert excavation. Atkinson also used a cutterhead attachment mounted on a Cat 416 loader for small scaling tasks.

Sandvik's range of electro-hydraulic roadheaders is split in mining models and tunnelling roadheaders. Until now there were two series, the MT300 series and the MT720, formerly know as Alpine Tunnel Miners. The MT520, is due to be introduced. All have transverse cutterheads for use in a wide range of rock types in main tunnel construction, rehabilitation and shaft sinking. As the largest, the MT720 can reach up to 6.6m and across a width of 9.1m from one position, and offers 300kW of cutter power from a total installed power of 555kW.

Shield machines

As befits its broad range of tunnelling equipment, Herrenknecht offers open-face shield machines equipped with either cutter-booms or backhoe excavators. Indeed some large diameter shields in the past have been equipped with multiple excavation units. The first Herrenknecht production was of backhoe shields.

Shaft sinking

With Herrenknecht VSM technology, shafts with large diameters (4.5-1.0m id) and depths of 25-80m, can be sunk quickly and safely. The shaft boring machine with excavation unit is braced using special adapter plates on the reinforced shaft support ring. The

Above: The transverse cutting head of a large tunnelling roadheader – Sandvik's MT720. Another model in the series is being introduced at Bauma this month;



Above: View from above shaft sinking operations in Naples using the Herrenknecht VSM method

Right: Another Alpine WS60 cutterhead mounted on a TeleBoom for shaft sinking in Australia



excavation unit has a cutting drum with special picks and which rotate whilst pivoting to loosen the ground to be excavated. The telescopic cutting boom can rotate by 190 degrees in both directions

The method can be used for starting or target shafts for TBMs of various diameters, and for ventilation or rescue shafts. Herrenknecht also promotes its use in a vertical underground car-park concept called U-Park. The method is now being used by Consorzio Icotekne in Naples, Italy, for ten 4.5m id shafts on Metro Line 1 of depths from 34 to 45m between Dante and Garibaldi stations. The shafts will be used for ventilation and emergency passenger exists.

Site advantages of the VSM method include low noise and vibration to avoid disturbance in urban areas, and a modular design for rapid set up, even on sites with restricted space.

A major advantage of the method compared to many other methods of shaft sinking is that the equipment can be used under water, allowing easier temporary support of the shafts walls

Cutters

An extension to the concept of flexibility is to remove the cutterheads from roadheaders and to attach them to more conventional excavators. It is often claimed that cutting or milling heads can perform quicker and are more environmentally friendly than hydraulic breakers mounted on a similar carrier. In addition to conventional hydraulic excavators,

cutterheads have also been applied to LHD vehicles and skid-steer loaders, especially for refurbishing or enlarging tunnels.

Cutterhead attachments have also been applied to less conventional equipment such as special long booms for profiling high caverns or to help in shaft sinking. With their hydraulic drives, cutterhead attachments can also be used underwater or on wet faces.

Alpine has carried the concept further with its Alpine Cutter Loader (ACL) that requires a standard or compact tunnel excavator, such as those by Terex, Liebherr or Caterpillar as mentioned before. In addition to a transverse cutterhead the excavator is also equipped with a loading apron and an underslung chain conveyor. The cutterhead can be used in rock of UCS up to about 70MPa, above which it should be exchanged for a hydraulic hammer says Alpine. For even harder, massive rock, a drill-boom can be attached for blasthole drilling followed by mucking out with a bucket or shovel attachment.

Sandvik also offers separate cutterheads in the MA series (formerly ATH). Three models are available with cutterhead power of 100, 200 or 300kW (models MA520, 620 and 720 respectively).

Excavation near existing CI linings – Part 2

This is the second and final part of a paper submitted for the 2009 BTS Harding Prize competition by Anmol Bedi of Mott MacDonald and Imperial College London and covers the response of cast-iron linings to adjacent excavation as in many metro station expansion projects.

There are a number of factors to consider when reviewing the consequence of joint distress. In particular, the situation of the bolts.

Joint distress with bolts tight:

The consequence of cracking in the end plates is dependent on the location of the cracking in relation to the tunnel face. Cracking of the end plates may only present a serviceability problem in a tunnel, which is completely confined by the ground, but can lead to accelerated radial rotations and eventual collapse if it occurs in a section where the ground supporting the lining has been removed.

Considering the example of the escalator barrel in fig. 5 (part 1, T&T March, p33), the highest joint rotations are expected at the axis. If the cracked plates also coincide with an area of unsupported ground, such as near the tunnel face (Fig. 9), or where the support measures have not gained sufficient strength to provide sufficient restraint against deformation, unexpected levels of joint rotation and stresses in other lining components may occur. The resulting cracking could lead to uncontrollable movements of the cast iron lining and eventual collapse.

This is especially critical for intricate tunnelling works where the new excavation

comes in close proximity, or exposes the existing cast iron linings. Fig. 9 shows a typical sprayed concrete lining (SCL) construction¹² adjacent to an existing cast iron lining. The area at greatest risk of joint overstress is shown.

Joint distress with bolts loosened:

Loosening the bolts helps to overcome the risk of damaging the segments by eliminating bolt tension and thus cracking of the end plate. However, this comes at the cost of reducing the ring stiffness. In London Clay, flexural stiffness of the ring is generally unimportant when the ring is embedded in the ground³. As a ring becomes unloaded, as a result of adjacent excavation, deformation will be resisted by this flexural stiffness. Thus by loosening the bolts, the ring deformation and joint rotation are likely to be much higher in magnitude and occur at a faster rate than with the bolts tightened.

Also, failure at the radial flange would occur when the bearing stresses at the flange tips exceed the minimum compressive strength of the cast iron. Thus accelerating deflections of the cast-iron lining in this way could potentially result in sudden failure of the radial flange. Conversely if the bolts are allowed to remain tight, yielding of the bolts and/or local distress of the end plate are easily detected, to instigate mitigation measures.

Response of flexible linings

The box excavation of Vaziri et al¹³ describes the irregular load conditions resulting in the linings undergoing large asymmetric distortions.

Morgan & Bartlett⁹ describe an experiment to determine the performance of local excavations in close proximity to the flexible tunnel linings located at Finsbury Park, London. The experiment involved excavation of unlined 1.8m-diameter shafts sunk 900mm clear of the tunnel.

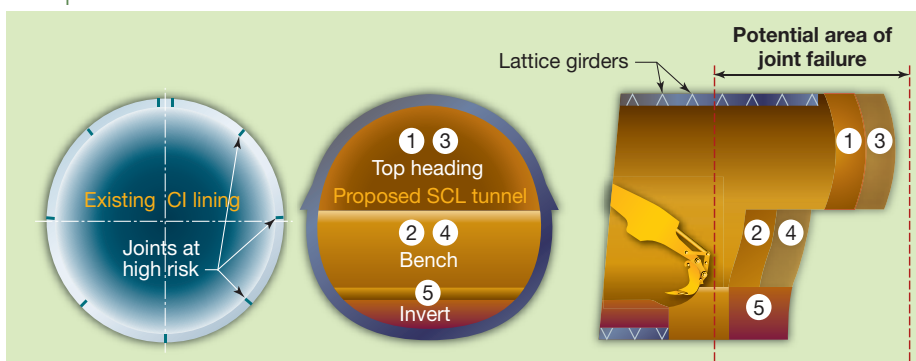
These experiments demonstrated that knuckle joints have the ability to resist local discontinuities. Whilst this is partly accounted for by the stiffness of London Clay, the above case studies indicate with reasonable certainty that these flexible linings are able to withstand non-uniform distortion and rotation of the knuckle joints without adverse impact. Failure in these linings is thus likely to occur from flexure in the segment bearing at the joints if intimate contact is not maintained due to rotation and buckling failure at higher deflection.

Analytical stress assessment

One of the most widely used methods of stress assessment utilises the elastic solution for a tunnel subject to uniform elliptical distortion.

The equation was first presented by Morgan⁸. This method assumes the lining is a continuous ring of uniform thickness. The presence of joints may be accounted for by reducing the lining flexural stiffness using the empirical formula postulated by Muir Wood (1975)¹⁰.

Other analytical solutions involve the assumption of rigid body rotation of the segments assuming stiff bearing at the joints. Such methods do not account for the flexural characteristics of the radial joints, and employ the use of Muir



Left: Figure 9 – Area of potential joint failure (van der Berg, 2003)¹²

Wood's empirical equation for reduction of lining inertia.

The deficiency of undertaking an analysis using Muir Wood's empirical formula is the empiricism implied in its use. The origins of the formula are not evident, though from precedent it seems its use in London Clay is warranted. However, in softer ground than London Clay or where the confining ground is reduced or removed, and the stiffness ratio of lining/ground becomes larger the stiffness of the lining joints becomes more significant. Deformations of the lining may well be larger if this formula were applied.

Numerical stress assessment

The advantage of undertaking numerical analysis is that the assumption of uniform elliptical distortion is eliminated; the distorted shape of the existing tunnel linings is better captured.

Explicit structural modelling of the segment geometry and each radial joint component in both 2- and 3-dimensional (2D or 3D) coupled soil-structure interaction analyses is overly time consuming and impractical. The model is simplified by modelling the lining as a continuous cylinder of uniform thickness. As such Muir Wood's formula is again applied to determine the moment of inertia of a segmental lining.

Adjacent excavations greatly reduce, or even remove, the soil-structure interaction between the ground and lining. Modelling a continuous lining using Muir Wood's formula, which in the author's view embodies ground-structure interaction, may be completely unrepresentative of the lining behaviour. Explicit modelling of the joint stiffness is required.

Proposed hybrid technique

To adequately capture the load-deflection behaviour of the cast-iron linings the author recommends a procedure that allows incorporation of the joint stiffness for prediction of the true deformed lining profile.

Firstly, the rotational stiffness of the radial joint is calculated using an analytical approach considering the radial joint geometry. The total system stiffness is derived through summation of the response of each component to a unit moment.

The joint geometry and defining equations are shown in fig. 10. Using these properties, an iterative solution to the two equations below is obtained to determine the spring stiffness constant (k).

$$(2 t_f + t_n) \cdot T = [\delta - (\alpha + \beta)T]E_D \cdot A_{bs} \quad Eqn 1$$

$$M = T(n_{av} - y_a) \quad Eqn 2$$

$$M = k\theta$$

Eqn 3

$$\delta = (n_{av} - x_a) \theta$$

$$T = \frac{\delta E_b A_b}{(2 \cdot t_f + t_n)}$$

$$\delta = \delta - \delta_f - \delta_p$$

δ_f ← deflection of flanges

δ_p ← deflection of end plates

The calculated value of radial joint spring stiffness can then easily be applied to a 2D or 3D, coupled soil-structure interaction model by modelling each segment connected by a series of torsional springs.

This method allows calculation of the deformation at which the allowable stress in the joint is reached. Furthermore, the use of numerical simulation will allow the deformed profile and joint rotations to be more realistically captured.

Such analyses will result in lower joint rotations than those calculated assuming rigid segments and uniform elliptical mode of distortion.

This analysis also allows explicit prediction of stress in each joint component (bolt, end plate, etc) permitting the visualisation of where failure is likely to occur.

Allowable deformation

The proposed analytical technique for calculating the joint rotational stiffness

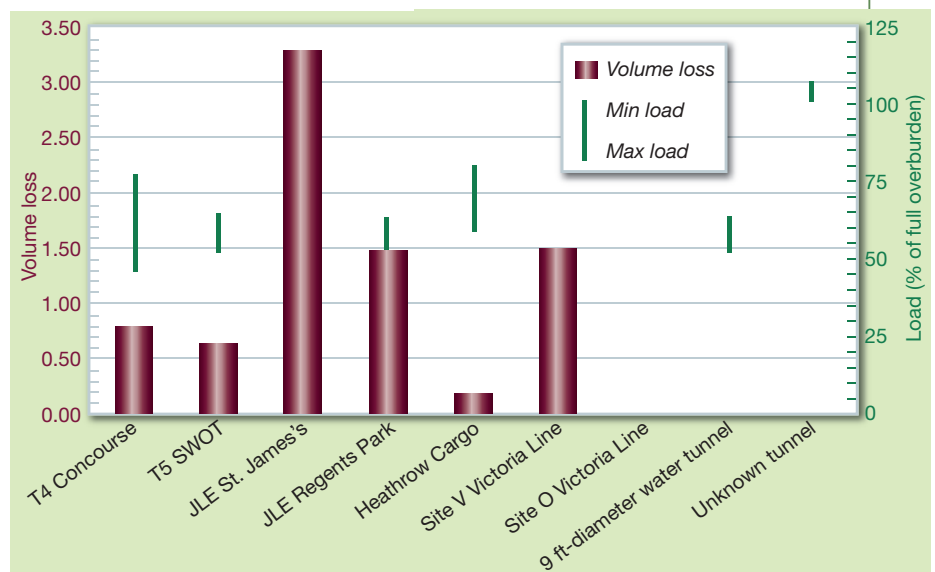
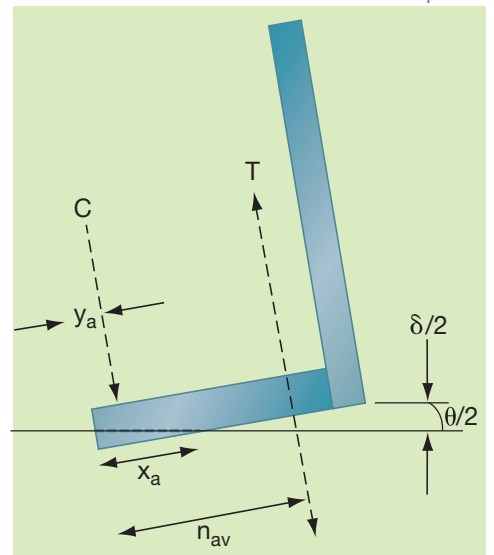
Left: Figure 10 – Free body diagram of radial joint forces

Below: Figure 11 – Measured axial forces in existing tunnel linings in London Clay

can also be used to determine the allowable joint rotation with the bolts remaining tight or loosened. This requires incremental application of rotations and applying Eqn 1 & Eqn 2 (above) to determine the tensile and compressive forces at the joint from the resulting moment.

Axial force & joint stress

The in situ axial loads present in the cast iron lining prior to construction of new works is of paramount importance in the prediction of allowable levels of joint rotation. Any existing axial loads will result in shortening of the segments in the hoop direction. Thus, for tension to be induced in the bolts, this initial compression must be released either through reduction in axial loads in the lining or further joint rotation.



Assumed in situ axial load: Tunnels in London Clay are subject to time-dependent increase in linings loads as a result of the short- and long-term behaviour of the clay.

Site monitoring of cast-iron linings constructed in London Clay show a rapid increase in axial loads in the short term followed by a gradual increase in load with time^{5,2}.

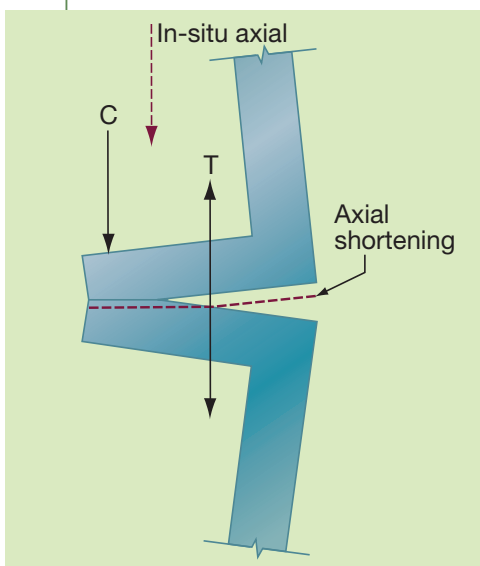
Investigations to identify the development of load carried by old-cast iron tunnel linings in London Clay have been undertaken by direct measurement (e.g. Ward & Thomas¹⁴; Barratt et al²). These studies suggest equilibrium vertical loads acting on tunnel linings between 60 and 100 per cent of the full overburden pressure. A summary of axial load and measured volume loss for various projects in London Clay is presented in fig. 11 (summarised in Powell & Clayton¹¹, Jones⁶).

There are many methods published for calculation of the in situ, long-term axial force induced in tunnel linings in an infinite elastic medium. Most widely accepted of these is the Curtis-Muir Wood solution for a circular tunnel in elastic ground³. This paper does not deal with determination of axial loads, though readers should refer to Kim and Eisenstein⁷ for a rigorous analytical method.

Axial load changes due to adjacent excavation: Using the hybrid method presented here, if an initial axial shortening using full overburden load is assumed, the required rotations to produce joint distress will be much larger than if no axial load is included.

Where new tunnels are proposed

Below: Figure 12 – Affect of axial force on allowable joint rotation



immediately adjacent to cast-iron linings, modification to the axial loads in the tunnel lining may result in a significant loss of the assumed in situ axial loads. Large open-cut excavations immediately above existing cast-iron tunnels have a similar affect. Therefore the assumed existing axial load in the lining has a large impact on the prediction of allowable joint rotations.

Fig. 12 shows the affect of in situ loading, joint rotation and the loads in the joint components. The dashed red line represents a condition where a significant portion of the overburden loading has been assumed, with the solid line indicating a condition of reduced or nil overburden. The joint rotation is constant for both.

For the reduced overburden case, the bolts are in tension, though they remain in compression in the high overburden case due to the axial shortening.

Definition of the in situ axial load is vital in determining the allowable level of rotation. An overestimation of the axial load may result in higher allowable rotation, which may lead to unexpected failures on site. Conversely, underestimation may result in unnecessary propping or support works installed within the existing cast-iron linings prior to adjacent excavation commencement.

Setting acceptable levels

The prediction of the in situ axial loads prior to any adjacent tunnelling works presents the designer with an immediate challenge. As the level of this load cannot be accurately defined, engineering judgement must be applied to derive allowable joint rotations and hence trigger limits during construction.

The complex interaction associated with the new, neighbouring excavations has the potential to reduce the axial loads in the lining to very low values. This is evident from the low lining forces resulting from the box excavation of the BBC case study (Fig.13)

Furthermore, slender pillars of ground between open excavations and the extrados of the existing cast-iron linings reduce the confining effect provided to the ring and reduce the soil-structure interaction, which may have initially been responsible for loading the lining. For construction of excavations adjacent to the existing cast-iron lining, it is conservative to calculate the allowable joint rotations using the proposed hybrid method, assuming a complete loss of axial force at the joint. The final decision though rests solely with the designer.

Generally varying levels of distress may be acceptable during adjacent

excavation works and trigger limits can be set so that appropriate mitigation measures are in place to ensure stability of the works. In the author's view, the following trigger levels may be deemed acceptable due to adjacent excavation works. It is emphasised though that the trigger levels, factors of safety and mitigation measures should be set after a thorough review of the reliability of material properties, implications of reaching these levels and the serviceability criteria of the tunnel in question.

- Green Trigger - All elements remain in the elastic region, using conservative material properties and substantial factors of safety (FoS).
- Amber Trigger - Calculation predicts joint elements reached theoretical elastic capacity. The theoretical capacity has been calculated using a substantial FoS (of 3) on the minimum tensile strength.
- Red Trigger - Calculation predicts joint elements reaching theoretical elastic capacity using a reduced FoS (2.5) on the minimum tensile strength. The bolts may have yielded at this trigger level. Rupture of the bolts is not predicted.

Instrumentation & monitoring

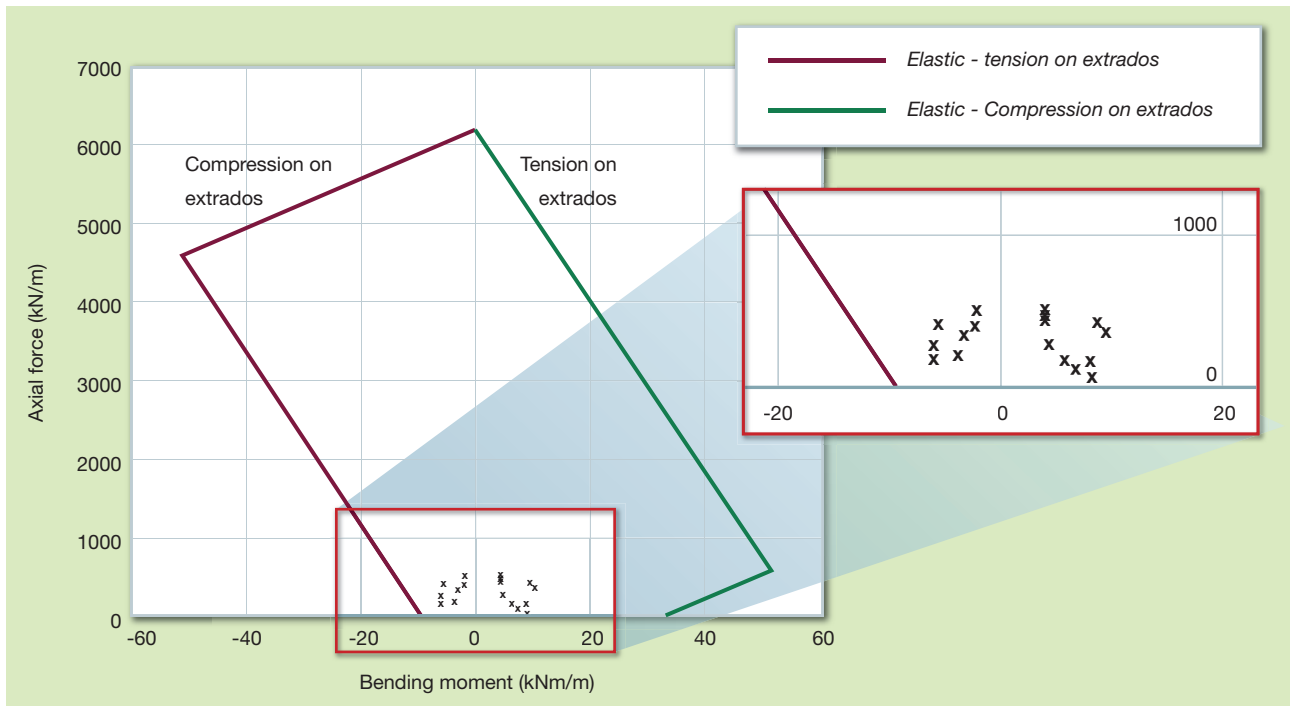
Conventionally the deflected shape of the lining and 'change in diameter' are typically recorded to determine the acceptability of the cast-iron lining to the adjacent excavation. This data is used to determine the 'ovalisation' for comparison with pre-set or predicted levels. This paper shows that explicit monitoring of joint rotation is of prime importance if the level of stress in the radial joint components is required. This is particularly important should the bolts remain tightened.

Joint rotation may be monitored using tilt meters or potentiometers directly coupled to the radial joints. The instruments should provide remote continuous data, with the outputs read in conjunction with lining deflection readings to assess trends.

If the bolts are kept tight, an acoustic monitoring system recording the noise generated through strains in the tunnel lining is also useful. Sharp changes in the acoustic signature can be used to determine the initiation of cracks and yielding. This system requires installation well in advance of tunnelling works so that a 'noise signature' can be determined as a benchmark.

Conclusion

Distress in existing cast-iron linings from immediately adjacent tunnelling and/or cut-



Above: Figure 13 – Predicated loads due to adjacent box excavation (Varizi et al)¹³

and-cover excavations leads to a complex change in the existing stress regime. This will result in deflection of the cast-iron lining, not uniformly elliptical as generally assumed in design practice. The use of simple numerical models coupled with torsional springs to represent the joint stiffness will assist designers to predict the response of existing cast-iron linings during critical construction activities, when failure is most likely to occur.

The use of the hybrid technique presented in this paper may result in lower joint rotations than those calculated assuming conventional closed-form methods. The hybrid technique also provides a rapid way of simplifying numerical models that may otherwise be too inefficient to undertake. Thus for a large-scale station improvement project, many simulations may be achievable. This analysis also allows explicit prediction of stress in each joint component (bolt, end plate, etc) permitting the visualisation of where failure is likely to occur.

A more accurate prediction of distress, and where and when it is likely to manifest itself, allows proposals that may hitherto be considered unfeasible constructions.

In critical areas where large deflections may be expected, lining deflections may be controlled by keeping the bolts tight and using a combined approach of stress

prediction, using the hybrid method, to set trigger levels coupled with site monitoring to ensure safe and efficient construction.

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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.

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

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

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

BRITISH TUNNELLING SOCIETY

15 APRIL 2010: **Harding Lecture – Risk vs Innovation**

Alistair Biggart presents this year's Harding Lecture. ICE, 5.30pm for 6pm start.

7 MAY 2010: **Annual Dinner**

The BTS Annual Dinner will again be held at the Brewery, the sixteenth year there. The society invites its members, their partners and guests to attend the dinner. Tickets cost £85.00 per head. Most people book by the table (10 or 12) but we welcome bookings of all sizes to form mixed tables. The speaker will be Gyles Brandreth. The Brewery, Chiswell Street London, EC1Y 4SD 7.00 pm for 7.30 pm - Carriages at 1am.

20 MAY 2010: **West Ham Flood Alleviation Scheme**

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

17 JUNE 2010: **Atlantic Sea Tunnels in Norway**

Prof. Eivind Grøv, vice president ITA and president of the Norwegian Tunnelling Society will speak on road tunnels and bridges being built along Norway's western sea coast. ICE, 5.30pm for 6pm start.

16 SEPTEMBER 2010: **Tunnelling in Seattle - Past, Present and Future**

How tunnels have been used in Seattle and why they are now starting to push the envelope in American tunnelling. The talk will look in detail at recent projects, particularly Brightwater, and at the planned 58ft diameter bore for the Alaskan Way viaduct replacement tunnel.

Brightwater is a \$2 billion new wastewater treatment system, which includes 14 miles of soft-ground bored tunnel. Currently under construction, the tunnels are being bored using 2 EPB and 2 slurry TBMs, and are notable for their long drives and high mining pressures.

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

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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