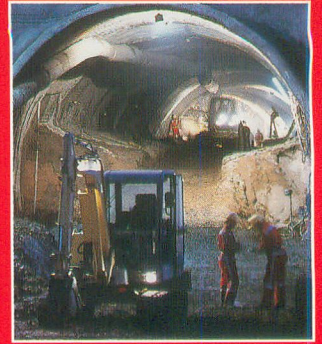


MAY 1999



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May - June 1969

Tunnels and Tunnelling

5s.



Photograph by courtesy of London Transport

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Zurich-Thalwil: Impressive Results

The Zurich-Thalwil section of the Swiss Railway's large-scale „Bahn 2000“ has achieved record results. With the newly constructed Herrenknecht TBM (diameter: 12.29m), the following results, which were the best until now, have been reached: **Monthly result: 547.40m, Weekly result: 144.50m, Daily result: 34.00m!**

A total of approximately 1,500 metres have been able to be tunnelled by the middle of April. Tunnelling is thus proceeding ahead of schedule along the Allmend-Brunau-Nidelbad section.

On March 31, the tunnelling of the second tunnel section, Almend-Brunau/Lochergut, was also able to be started on time. The newly constructed HERRENKNECHT Mixshield (diameter: 12.39m) can be switched from hard-rock to slurry mode within the tunnel itself.

Both machines, which will be used to tunnel geologically

different sections, work through the ground in opposite direction in starting shafts which are only 50 metres away from each other. The 5,700-metre-long Allmend-Brunau/Nidelbad section lies entirely in rock and contains the side tunnels (length: 229 m/215 m) of the structure connecting Nidelbad with both single-track tunnels toward Thalwil (length: 1,309 m/645 m). For logistical reasons, the first 335 metres of the tunnelling section was carried out with a significantly shortened machine and a provisory conveyor. Since the complete assembly of the system in the beginning of February 1999, over 1,000 meters have already been mastered.

The 2,620-metre-long Allmend-Brunau/Lochergut section changes to a loose-stone (water-bearing sihl ballast) section after a hard-rock section and must be tunnelled through with low coverage by means of a Mixshield. The Mixshield is accordingly converted from hard rock to slurry mode. Due to the lack of space, a shortened version was used first.

After a hard rock section, the 2,620-metre-long Allmend-Brunau-Lochergut section switches to loose rock (water-bearing sihl ballast) and must also be tunnelled through with low coverage. A Herrenknecht Mixshield which



Two newly constructed Herrenknecht machines are being implemented in the Zurich-Thalwil project: The record setting TBM (12.29m diameter) and a 12.39m Mixshield (photo). Tunnelling with this from TBM to slurry convertible machine has commenced on March 31st.

can be switched from TBM to slurry mode within the tunnel will be used for this purpose (start of tunnelling in the spring). The Zürich-Thalwil tunnel (total length: 10.7 km) is the first part of the planned Zimmerberg Base tunnel. This core piece of the „Bahn 2000“ project of the Swiss railway is intended to relieve

the heavily used lake line in Zurich and to act as an important connection to eastern and central Switzerland and the canton of Ticino.

The second part (Nidelbad-Litti, 11,200 m) is still in the planning stage. There is an option of extending the tunnel within the scope of the AlpTransit project. ●

Data & Facts

Tunnelling project

Double-track tunnel for project „Bahn 2000“

Project owner

Swiss railway

Client

Zurich-Thalwil Tunnel Joint Venture (AZT): Zschokke Locher AG, Prader AG, CSC, Murer AG, J. Scheifele AG, Specogna & Co, Wayss & Freytag AG.

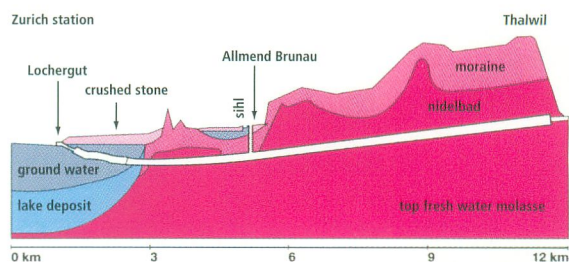
Tunnelling Machine Data S-139

machine type
TBM in shield, ø 12.29m
weight approx. 1,700tons
length 180m
connected load 3,300kVA
max. thrust force 63,700kN

Tunnelling Machine Data S-140

machine type
Mixshield, ø 12.39m
weight approx. 2.000tons
length 212m
connected load 3,750kVA
max. thrust force 104,000kN

Zurich HB—Thalwil /logitudinal profile of the geological situation



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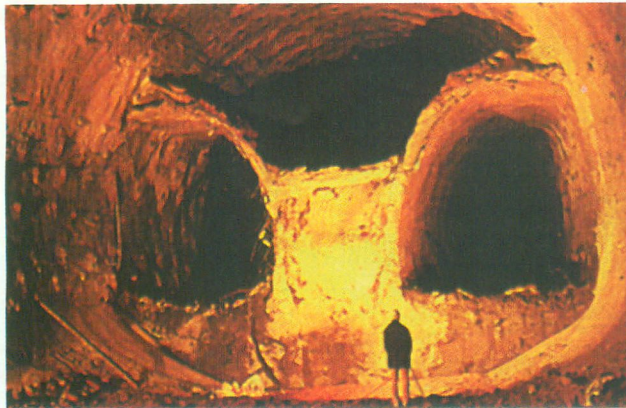


FRONT COVER: the cover of the first issue of *Tunnels and Tunnelling*, which published articles from Denmark, South Africa, Mexico and the UK, together with technical features on large diameter shields and blast damage assessment
Inset: heading and bench of the Ristet tunnel, Zurich

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Project examples

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USA (Texas)
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Bosten Outfall Tunnel

Switzerland/France
Vereinatunnel
Gotthard base tunnel
Alpetunnel
Lötschberg base tunnel

Denmark
Great Belt Link

South Africa (Lesotho)
Lesotho Highlands Water Project

Asia
Young Dong Railroad Relocation Project, Korea
Eastern Expressway Suao - Hualien, Taiwan
Wanjiazhai Yellow River Diversion Project,
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HSR Taipei - Kaohsiung, Taiwan

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INSIDE NEXT MONTH

■ **North American focus.**

Tunnelling activity in this huge market for new build, expansion and rehabilitation of underground infrastructure is highlighted in features covering prominent projects from Honolulu and New York.

■ **Technology review: mucking out.**

Tunnelling machine productivity depends upon the efficiency of mucking out systems. We look at the contributions made by the leaders in the field and examine the latest developments in the technology.

■ **Immersed tube tunnels.**

There are an increasing number of immersed tube structures in use around the world. We consider this form of tunnel construction through a paper on the design of a proposed floating immersed tube tunnel in Norway.

■ **Roadheaders.**

The relationship between geological features, cutting performance and bit wear on roadheaders is examined by means of four German case histories in this report.

■ **British Tunnelling Society.**

This month's BTS presentation is a report on the recent debate: "This house is of the opinion that compensation grouting is the panacea for all tunnelling ills."

Counting the cost of the Mont Blanc fire

In the aftermath of the horrific Mont Blanc Tunnel fire, where an estimated minimum of 40 people perished, it is only to be expected that the recriminations will fly as a full investigation of the disaster is undertaken by the French and Italian authorities (*World News*, p6). But, inevitably, alongside the performance of the operating company and the emergency services, the whole concept of tunnelled road links along main trunk routes will be put in the dock.

Early reports and comments in the media point to gross traffic overloading, inadequate maintenance, ageing design and poor management by the operating company as reasons behind the fire. Yet, in the minds of the general public, these points will be combined in the simplistic view that tunnels are inherently dangerous, and this is bound to have an impact on future infrastructure investment decisions.

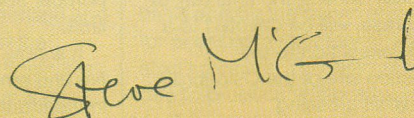
Of course, the performance of a tunnel after it has been handed over to the client is out of the control of the designers and builders. While immense effort is spent in ensuring safety during the design and construction processes, safety in operation is another matter. All the builders can do is strive to ensure that the structure features the best design and the highest quality of construction.

However, the potential for fatalities during the operating life of a tunnel is far higher than during the relatively short construction period, and demands equal, if not greater, attention.

President Chirac's assurance that French tunnels will be closed if they fail to meet safety standards is welcome. But, surely, such tunnels have no business being in operation at the present time.

With hindsight, one might question whether we have been exceptionally lucky over the past 30 years not to have seen more accidents and fires as traffic levels in long road tunnels worldwide have risen so that they far exceed their original design limits and where speed limits within tunnels are routinely flouted.

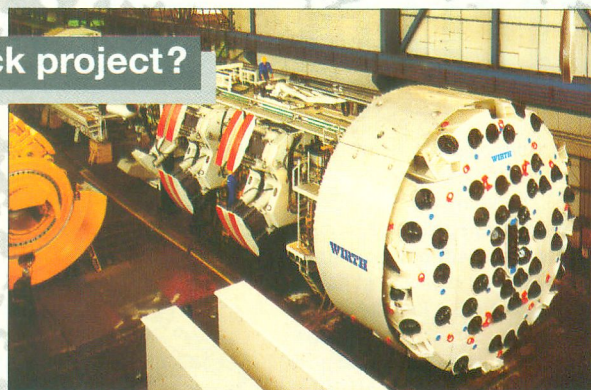
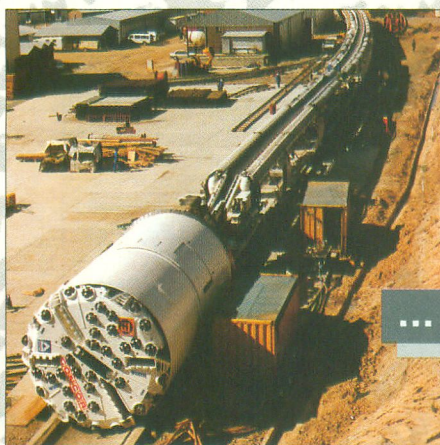
It is more than time to look at the safety standards employed by operators before the tide of public opinion turns against the concept of underground infrastructure development completely, at the very time when it is becoming increasingly recognised as the most effective way forward.



"It is more than time to look at the safety standards employed by operators"

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Taiwan rail boom

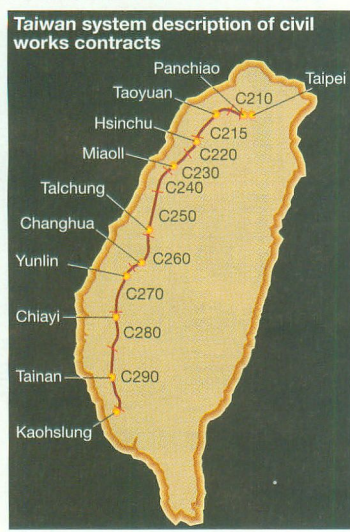
Taiwan is pushing ahead with plans to develop its US\$12bn high-speed rail line between the capital Taipei and the southern port city of Kaohsiung, together with a US\$6bn metro system in Kaohsiung.

Kaohsiung City Deputy Mayor Hou Ho-Shong told *T&I* that the two schemes are part of a US\$45.45bn 10-year infrastructure spending boom.

The Taiwan High-Speed Rail Corporation has just invited tenders for return in June for the ten design+build contracts on the 345km high-speed railway.

Seven contracts have tunnelling components, including the 2.2km Hueilung Tunnel and 6.4km Linkou Tunnel near Taipei in Contract 210. The 4.3km Hukuo Tunnel is included with cut+cover tunnels in the 40.5km Taoyuan section (Contract 215). Other key tunnel sections are the 3km Miaoli Tunnel (Contract 240) and the 7.3km Paghuashan Tunnel (Contract 260). About 48km of tunnel will be built altogether.

The Rail Corporation has refused to name the 21 prequalified groups bidding for a maximum of two contracts each. But it has confirmed its current group of advisers include Parsons Brinckerhoff International



as project manager; the UK's NNC as seismic consultant; and Balfour Beatty/Cogifer/Heitkamp as track specialist.

Ground breaking ceremonies were held on April 5 at Chayi Station and at the depot site at Kaohsiung on March 26.

The corporation, a group of mainly Taiwanese investors, must choose which high-speed train system to use. A Taiwan-European group including GEC, Alstom and Siemens was favoured, but a Japanese group is also competing for the double-deck system. In Kaohsiung, Deputy Mayor Hou said three groups are chasing a massive deal to develop two underground rail lines in the city.

One venture comprises mainly French companies. A second includes the UK's Balfour Beatty; China Steel; and two Taiwan contractors, BES Corp and Ret-Ser

Engineering. A third is a Canadian/local venture, including Bombardier Transportation.

A winning JV should be appointed in October 2000, according to Hou, following a delay caused by political wrangling.

The US\$6bn mass rapid transit system comprises two lines totalling 42.7km. The 28.3km Red Line runs east-west and includes 19.8km of tunnel. The 23 stations will all be built underground.

The 14.4km Orange Line, running north-south, will be built entirely underground, including the 14 stations and the main depot.

Funding was finally approved by the city council in 1997 after a series of rows which have delayed the scheme by about three years. Despite this approval, the council is keen for each of the three groups to include financing options as part of their bids. **T&I**

Taiwan high-speed rail implementation system: key civil works features

Contr. No.	Length (km)	Key Features
C210	11.3km	The major feature of this section are the Hueilung Tunnel (2.2km) and the Linkou Tunnel (6.4km).
There are also some viaducts		
C215	40.5km	The Hukuo Tunnel (4.3km) is in this section of the alignment. the guideway runs through Taoyuan Station and includes cut+cover tunnels, viaducts and cut & fill sections
C220	17.8km	This section consists of numerous short tunnels, some viaducts and cut & fill. It runs through the Hsinchu Station.
C230	23.4km	This section consists of numerous short tunnels, some viaducts and cut & fill. It runs through the Miaoli Station.
C240	20.8km	This section includes the Miaoli Tunnel (3.1km), other short tunnels, viaducts and cut & fill.
C250	39.8km	This section comprises mainly viaducts but includes some short tunnels and cut & fill. Taichung station is in this section.
C260	36.6km	The longest tunnel on the alignment, Paghuashan Tunnel (7.3km) is in this section. It also includes viaducts and cut & fill sections. Changhua Station is in this section.
C270	42.8km	This section comprises viaducts and cut & fill. Yunlin Station is in this section.
C280	34.5km	This section is comprised entirely of viaducts and cut & fill. Chayi Station is in this section.
C290	58.8km	This section is comprised entirely of viaducts and cut & fill. Kachsiung Station is at the end of this section.

IN BRIEF

Serbian water bids

The Electric Power Company of Serbia, Elektroprivreda Srbije (EPS) is inviting bids to finance the second half of the water transfer scheme from the Toplodolska river to the Zavoj reservoir for the hydropower station at Piroat. The water is to be transferred along a 5 625m long 3.6m wide diversion tunnel. The tunnel has been excavated 2300m so far. The costs for completion of civils works is estimated at \$11m with completion scheduled for the end of 2000.

US Tunnel ceiling collapse

Two reinforced concrete panels 3.3m long and 3.3m wide weighing 3-4 tonnes each fell onto three westbound lanes of rush hour traffic during a ceiling collapse in a bridge-plaza tunnel on US195 in Massachusetts, US. Poor drainage is being blamed for the collapse and there is uncertainty over who is responsible for maintenance. The incident caused several accidents resulting in injury but no fatalities.

UK rail expansion

The UK rail infrastructure company, Railtrack is to spend \$42.9bn to expand the rail network by 30 per cent over the next ten years. \$636m will be allocated to adapting tunnels and bridges to allow the use of larger freight container wagons.

More wrangling on the Delhi Metro

The Archaeological Survey of India has become the latest body to raise objections to the construction of the metro in Delhi. It has warned the Delhi Metro Rail Corporation to avoid any damage to sites of historical interest that lie close to the metro route. This comes after shopkeepers in the path of the elevated section of the

metro protested about a lack of information on compensation and alternative sites. (*T&I*, Dec '98 p13).

Tunnelling on the \$US1.14bn first stage of the Delhi Metro is due to begin in early 2000. The 55.3km route includes the construction of 10km of 5.4-5.8m i.d single-track tunnels at depths of 18-21m. A TBM will be used in rock, a shield in

soft ground and some areas will require drill+blast. Completion date for the first stage is 2005, but DMRC and design consultants, a JV of Pacific Consultants International of Japan; Parsons Brinckerhoff of the US; Jarts; Tonichi; and Rail India Technical and Economic Services (RITES) have yet to tender work to contractors for the alignment. **T&I**

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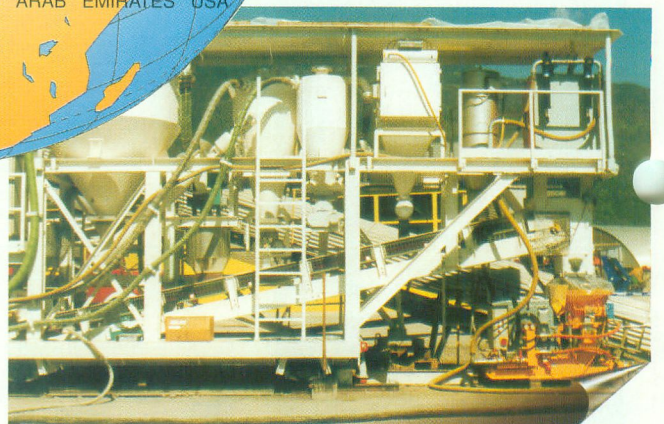
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North Downs tunnel start

Excauation of the 3.2km North Downs tunnel, part of package 410 on section 1 of the Channel Tunnel Rail Link in Kent, was due to begin in mid-April as T&I went to press. The project involves the construction of one of the largest cross sectional area twin rail track tunnels to be built in the UK.

Tunnelling will be carried out using the sprayed concrete lining method through upper and middle chalk with flint beds typical of South East England. Tunnel and portal excavation will be undertaken using a Paurat E242 Roadheader and a Liebherr 932T excavator to achieve the 12.5m high, 14m wide, 160m x 2 excavation dimensions. A Liebherr 564 loading shovel will remove spoil

via a conveyor system. To maintain rock strength, rockbolts will be installed using an Atlas Copco L2 rig with a man access basket. A Normet 9150 spraying system will be used to apply the wet primary concrete lining. The secondary lining will be constructed using in-situ cast concrete, with a final tunnel cross sectional area of 150m². All concrete will be batched on site totalling 40 000m³ of sprayed concrete and 140 000m³ of in-situ concrete.

The contractor on the \$127m project, EuroLink, is a JV of UK company Miller, Dumez-GTM of France and Beton-und-Monierbau of Austria. Work on the project is scheduled for completion in April 2002.



The Country Portal Site of the North Downs Tunnel, part of package 410 of the Channel Tunnel Rail Link

China hydro expansion potential

Preparatory work for a third huge hydro electric scheme on the Liang Can river in the Yunnan province of south western China could start this year, T&I was told during a recent visit to the country. Designs for the 4,200MW scheme, at Shau Wan, featuring approximately 4million cu m of underground excavation, are already completed and the scheme is now awaiting official approval. According to Professor Hu, project director of the nearby 1350MW Da Chao Shan scheme, currently under construction, there is tremendous potential for future hydroelectric development in China. "Only about 10% of the potential in China has yet been developed," he told T&I during the recent visit. "Of course this means that there is still 90% still available, which offers a big opportunity for our contractors and for importers to enter into co-operative agreements as there is great demand for high tech equipment and materials." He confirmed that on the Liang Can river alone, a total of seven schemes are planned - including Da Chao Shan and the already completed Man Wan schemes- plus another across the border in Tibet. The total output from these schemes when completed will be around 17,600 MW, or 80.7GWh annually. The timescale for these developments is dependent upon the availability of funds and economic conditions. For example, a 1,500 MW scheme, at Jin Hong, to be built in co-operation with Thailand, is currently on hold.



IN BRIEF

Boston clean up

The Massachusetts Water Resources Authority (MWRA) has released figures showing its commitment to reducing discharge of storm water and raw sewage, with more schemes similar to the Boston Harbour project. The MWRA is planning construction of a tunnel and pumping station to eliminate sewage discharges to South Boston beaches.

Trade in Japan

The 37th International Exhibition for Construction Equipment and Technology will be held at the Exhibition Centre in Tokyo, Japan from July 14-17. The event, called Conet '99 is expected to attract more than 70 000 visitors to what is arguably Asia's largest construction equipment exhibition. More than 170 companies are expected to exhibit. Contact: Tel (81) 332 636 881 Fax: (81) 332 637 077

White finger costs

Implementation of the Health and Safety Executive (HSE) standard "Safety in Tunnelling", including moves aimed at preventing 'white finger', could seriously affect small sub contracting businesses, according to reports in the UK construction press. White finger is an issue that the HSE intends to prioritise and current recommendations mean that hand held tunnelling drills would only be used for periods of up to ten minutes.

Dutch-German rail link begins

Work has begun on the first ever double-tracked rail tunnel to be bored in the Netherlands. The 3.4km Botlek Tunnel, constructed by the BTC Botlek JV for the client NS Railinfraabeer and the Ministry of Transport, Public Works and Water Management, will pass under the river Oude Mass in the Rotterdam harbour. It is the first of four tunnels on the 160km Betuweroute rail freight link between Rotterdam and the German border. Of the 3.4km tunnel, 1 850m is being bored using a 9.65m diameter Herrenknecht EPBM. The cut-and-cover

approaches on the river banks makes up the remaining 1550m. The finished tunnel will have an 8.65m i.d, lined with prefabricated concrete segments. Each tunnel ring is made of seven segments and one closing segment. The tunnel will have a maximum gradient of 2.5% and the deepest position of the top of the tunnel will be 20m below sea level. Construction is being undertaken through very soft holocene clay and peat layers. The Botlek tunnel is scheduled for completion in early 2002 at a cost of US\$244m. It is the first time an EPB shield has been used in these ground conditions in the

Netherlands, so the Dutch Centre for Underground Construction will be monitoring the project closely. The four other tunnels along the Betuweroute are the Sophia rail tunnel which will be a 7.8km bored tunnel running under the river Noord, polder Sophia and de Rietbaan; The Pannerdensch Canal tunnel which is a 3.8km tunnel that is still under design; and the Zevenaar tunnel which will be a 2.5km cut-and-cover tunnel. The Betuweroute is currently the largest infrastructure project in the Netherlands and is the first double tracked railway line to be specially constructed for freight





The face of innovation

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The Daini Shibisan Tunnel is one of the 13 tunnels being constructed for the Japanese high-speed train, Kyusyu Shinkansen, on the island of Kyusyu south of the Japanese mainland. These tunnels will significantly improve the communication between

JAPAN

the cities of Kagoshima and Kumamoto.

The length of the Daini Shibisan tunnel is 3,4 kilometres and the total length for all the 13 tunnels is 69 kilometres. The cross-sectional area of the tunnels is 73 m². When constructing the Daini Shibisan tunnel complicated ground conditions were encountered. Weathered sandstone was encountered as well as shale and clay. On top of this large water inflows occurred which resulted in that the holes drilled for rockbolts collapsed almost immediately.

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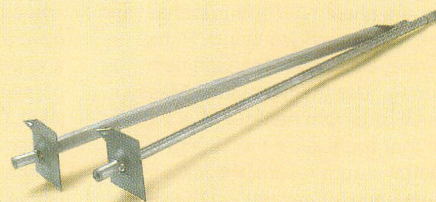
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The race for space in Oz

An enthusiastic audience assembled in Melbourne in March to participate in the 10th Australian Tunnelling Conference. This forum was devoted to tunnelling projects and technological developments in Australia and the Asia-Pacific region, the latter including presentations from Singapore, Thailand, Vietnam and Malaysia.

A recurring theme of the conference, which was organised by the Australian Underground Construction & Tunnelling Association, was the integrated planning of underground space as the surface of the world's cities becomes more and more congested. Speakers stressed that it was imperative for politicians and urban planners to join with their civil engineering compatriots to provide an integrated approach to planning such underground solutions.

But despite pressing invitations to Melbourne, politicians and planners had stayed away.

Delegates were told that capital for financing expensive underground projects is being raised increasingly by the private sector. The public-private partnership (PPP) ideal was advocated in a keynote speech by Willy De Lathauwer, Vice President of the International Tunnelling Association. He told his

audience about the High Level Group formed by the EU to address this matter.

The conference was introduced by H E The Honourable Sir James Gobbo, Governor of Victoria, who emphasised the integrated planning approach: "There are many compelling moral, economic and social reasons why Australia should consider an imaginative and expanded population target, provided we can handle the social and environmental issues involved. Those include . . . population increase in our cities and so new attitudes to infrastructure are vital, such as the possible undergrounding of major facilities."

The conference and accompanying exhibition were sponsored by Transfield Obayashi; Concrete Constructions; Halcrow; Australian Mining Consultants; CETCO; Geotest Instrumentation; Blastronics Systems and Services; Clough; Pasmenco; Terratec Asia Pacific; Geological Association of Canada; Connell Wagner; and Nordberg Australia.

A whole session (and site visit) was devoted to the tunnelling aspects of the Melbourne City Link, (T&T, July '98, p28). This 5km, 3-lane tunnel, built under a BOOT contract, is due for commissioning in December 1999. **T&T**

San Diego outfall

The South Bay Ocean Outfall in San Diego is up and running following three years of difficult tunnelling through bad ground. The project involved the construction of a 5.6km high pressure tunnel, claimed to be the longest single pass high pressure tunnel of its kind.

To build the tunnel, with a contract value of \$88m, the Traylor Brothers/Obayashi JV chose a 4.3m diameter EPBM built by a JV of Boretac and Mitsubishi. The EPBM was equipped with a 50m screw conveyor, claimed to be a record length by the project team. The tunnel lining comprised four precast concrete segments and a key and had a 3.6m i.d. Local geology varied from clays with high water content to boulders, which at one stage threatened to jam the machine's screw conveyor

Client the San Diego Metropolitan Municipal Wastewater Dept. devised the scheme as part of the city's \$1.2bn programme to improve coastal water quality. The outfall is part of the new South Bay International Wastewater Treatment Plant. It will treat overflows in Tijuana, Mexico, that were released into the Tijuana River when the system reached capacity, causing sewage spills on to local beaches.

The outfall includes a \$9.9m pipeline connecting the new plant to a 65.8m deep, 11.8m dia. drop shaft. The base of the shaft is connected to the 5.6km long tunnel that carries the effluent to a 46m long, 2.9m dia. riser. This discharges through two 658m long diffuser legs. **T&T**

IN BRIEF

Pipejacking saves on costs

Pipejacking has significantly reduced the cost of replacing 2763m of 2.6m diameter storm sewer pipes in Evansville, Indiana, US. Jay Dee Contractors won the contract with a bid of \$11.18m. It plans to excavate with a TBM and then jack the pipes in sections of up to 320m. The pipeline runs under a four-lane roadway and the technique will avoid costly traffic disruptions.

Pakistan power scheme

A hydroelectric scheme costing \$850m is to be built in Pakistan on a BOT basis. The Kohala scheme will include a 372m tunnel that will divert the Jehlum River. Norconsult of Norway has completed the feasibility study.

Fresh concerns over JLE schedule

Fresh concerns are being aired regarding the opening of London's Jubilee Line Extension in time for the millennium. A report from the Culture, Media and Sport select committee showed concern over what it describes as London Underground Limited's casual attitude to contingency planning. However, UK Deputy Prime Minister John Prescott told MPs at the end of March 99 that the JLE would be open in time for millennium celebrations.

Channel Tunnel tops the polls

The Channel Tunnel has been officially voted the greatest construction achievement of the 20th century. It beat tough competition, including the Hoover Dam and Chek Lap Kok Airport.

International construction industry specialists voted for the ten greatest construction achievements of the century. The results were announced at the Conexpo exhibition in Las Vegas, organised by the US-based Construction Industry Manufacturers Association (CIMA).

Roger Sainsbury, president of the UK's Institution of Civil Engineers said: "The Channel Tunnel is a tremendous feat of British and French civil engineering. The unique physical challenges which were faced and overcome will hopefully serve as inspiration for the future generations of this profession. **T&T**



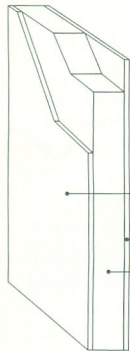
Work under way on one of the marine running tunnels for the Channel Tunnel

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Taiwan for ITA membership?

Admission of Taiwan to the International Tunnelling Association (ITA) will be discussed at the coming ITA general assembly meeting of the Executive Council in Oslo, later this month.

Acceptance as a national member of the 45 member-nation general assembly however seems difficult since the Peoples Republic of China is already a registered member nation and Taiwan is not recognised as an independent nation by the ITA charter written in 1979. However, the ITA executive Council could consider accommodating Taiwan by making similar arrangements as other international organisations, such as the WTO (World Trade Organisation), APEC (Asia Pacific Economic Council) which accept

both countries.

Taiwan has recently applied to join the WTO which will open Taiwan's enormous domestic construction industry to standard international trading rules and all government funded construction projects above a threshold value would then have to be opened to international tender.

Taiwanese delegates currently attend ITA general assemblies as individual affiliate members and several Taiwanese companies are affiliate members. In the meantime, Taiwan is establishing a national tunnelling society (another prerequisite for ITA national membership) and a special committee is revising regulations by which government contracts are procured and executed.

Prof. Dr. Alfred Haack, current President of ITA, said: "Without any doubt we recognise the tremendous and impressive effort the Taiwanese are taking to improve the infrastructure of their country concerning urban mass transit as well as long distance railway and road links. We like to support their remarkable tunnelling activities and invite them to play an active role in the international exchange of technological experience."

He continued: "The best way for that is through the ITA working groups dealing with various and most important fields of the art. We appreciate all ways leading to a more intensified co-operation, for example an international tunnelling workshop held in Taiwan in the near future." **T&I**

Millennium water main

Shown below is the cutterhead shield section of the Iseki TCC1200 Unclemole after its recovery from the last drive of the Nunhead -Deptford Trunk main. This major water main will feed the Millennium Dome site in east London. The breakthrough occurred in the first week of February completing the final 222m of the 1816m, 1200mm i.d drive using mechanised pipe jacking. The contract was completed by the JV of Barhale Construction and McNichols Construction. For a full report on the project see p39. **T&I**



Iseki TCC1200 Unclemole following recovery

China calls for more

Chinese transport experts, including officials from the Ministry of Construction's subway and light rail department, are calling for the development of more urban rail systems to ease traffic congestion and pollution. They said over the next 30 years Chinese cities with a population of more than 5 million should develop their own rail network to serve at least half the population. But officials recognise the present construction of a subway system is comparatively expensive. Construction of each 1 km of metro using domestic equipment costs about \$60 million. Using foreign equipment pushes the costs to

between \$85 and \$100 million. They have urged the central government to use foreign concessionary loans to build, upgrade and manage urban rail transport. So far a dozen cities in China plan to build more than 20 rail lines. Shanghai's second subway line, Beijing's Fuxingmen-Bawangfen subway, Guangzhou's second metro line and Shenzhen's first subway are already under construction or at the advanced planning stage. In addition, Nanjing, Wuhan, Chongqing, Changchun, Dalian, and Beijing's northern outskirts are preparing to build rail systems. **T&I**

Tunnel Construction & piling 99

Over 80% of available stand space at the UK's Tunnel Construction & Piling 99 symposium and exhibition has been sold. Held this year on the 8th -10th September at London's Olympia II Exhibition Centre, the event covers plant, processes, ancillary services and technical support used for the design, maintenance, refurbishment and construction of tunnels for civil and mining engineering world-wide. It also covers the design and construction of piling and deep

foundations for tunnelling and underground works. Visitors and delegates to the conference will be specifiers and decision makers from international client companies, contractors and consulting engineers. It is being organised by Brintex on behalf of the Institution of Mining and Metallurgy, the British Tunnelling Society and the Federation of Piling Specialists. For further information tel: +44 (0) 171 973 6663 or fax: +44 (0) 171233 5054. **T&I**

IN BRIEF

Concrete Europe 99, London venue

Concrete on Site will be the theme of Concrete Europe 99, to be held at London's Wembley Exhibition Centre on October 20-21. Already over 50 companies from the US and Europe have reserved space and the organisers are looking into the possibility of expanding into an adjoining hall. Contact Tel: +44 (0) 1235 522770/1 Fax: +44 (0) 1235 522070

Thailand choose US companies

US company Camp Dresser & McKee International Inc. will head engineering and construction on a design and build wastewater project near Bangkok, Thailand. The 140 million gallons per day first phase collection and treatment project will cost \$600m and is set for completion by 2001. The project includes 125km of sewer pipes.

New pipes for LA

The Los Angeles Dept. of Water and Power is to replace 240km of 50 year old large diameter riveted steel trunk lines. The \$450m project is expected to take up to 20 years and will be completed in phases. Pipe diameters on the first phase could reach 2.6m and engineers anticipate the use of jacking or micro-tunnelling at major intersections.

IN BRIEF

Engineering assets conference

ERA Technology has organised the conference 'Engineering Asset Management 1999' to be held at the Earls Court Conference Centre in London on October 6-7 1999. The conference will take a pragmatic approach to optimising maintenance management. Topics include: aligning maintenance strategies to key business objectives; monitoring the rate of change of risk over time; choosing between maintenance and renewal; getting the most from outsourcing; managing crises and benefiting from private finance initiatives. For further details:- Tel: +44 1372 367.125

Competition forces price cuts

Contractors and consultants in Hong Kong have had to reduce prices by up to a third because of a decrease in work. The economic crisis in Asia has resulted in stiff competition from outside contractors and consultants which are vying for projects in the more lucrative Hong Kong construction market.

Kier on the up

Kier has lifted pre-tax profits to \$7.5m in the six months ending December 1998, compared to \$6.2m for the same period in 1997. Kier has also increased construction turnover by 33% to \$670.5m, lifting pre-tax profits 20% to \$8.6m.

Lovat certified

TBM manufacturer Lovat has been registered as a ISO 9001 Certified Company after it was awarded ISO 9002 in July 1998. This marks a significant milestone in the growth of the company.

Svedala in distribution deal

Svedala Industri has signed a distribution agreement with Boart Longyear, a world leader in rock tool manufacture. The agreement provides the Swedish company with a more complete range of products in the drilling field. The new products, Svedala Rock Tools, will be marketed through the nearly 200 Svedala Houses in 50 countries.

French loans to Shanghai

The French government is to offer two concessional loans to help to complete Shanghai's third underground rail line and construct a water treatment plant in the city.

The deals were signed in mid-March by Chinese Trade Minister Shi Guangsheng and will be counter-signed soon by the French Minister of Finance, Economics and Industry, Dominique Strauss-Kahn in Paris.

The contracts stipulate that the

French government will provide preferential credit up to \$181m for the metro project and a \$24.5m loan to finance the Longxi water plant in Shanghai.

The Shanghai metro is one of the leading cooperative projects between China and France. During French Prime Minister Lionel Jospin's visit to China last year, Chinese and French companies signed a letter of intent for the manufacture and supply of metro vehicles.

UK pipe makers join forces

Subject to an agreement on conditions, Hepworth Building Products is to acquire the clay and plastic pipe interest of Naylor Industries plc. The acquisition should be completed by summer this year.

The two companies have been the only manufacturers of clayware jacking pipes in the UK, and Naylor has recently been enjoying considerable export success, with microtunnelling projects in Austria and the Middle East as examples.

Hepworth is the larger company, having substantial overseas interests, and offers a wider range

of construction materials which include concrete jacking pipes.

The combined Naylor and Hepworth clayware and plastics pipe products will be marketed as Hepworth Drainage. Edward Naylor, currently managing director of Naylor Industries, will be divisional MD. He will report to Stephen Bird, MD of Hepworth Building Products.

Coincidentally, both Hepworth and Naylor were instrumental in the development of clayware pipes for pipejacking and refurbishment, and are headquartered near each other in Yorkshire.

AMEC results show growth

AMEC plc has announced its audited annual results for the year ended December 31 1998, showing a 50% increase in pre-exceptional profit to \$113.5m. The company reports a 24% growth in profit from services activities to \$60.9m.

Diluted earnings per share increased 57% to 17.3 pence and dividends increased by 25% to 6.25 pence per share.

The strong net cash position was \$154.5m, with a group order book maintained at \$4.8bn. Sydney

Gillibrand CBE, AMEC group chairman, commented: "AMEC is in very good shape. We are well positioned to continue to make progress with our strategy and we expect to deliver further profit growth in 1999. The 25% increase in dividends reflects the board's confidence for the future."

Commenting on future company strategy and outlook, group chief executive Peter Mason said, "in summary, the outlook for AMEC is favourable. We expect 1999 to be a good year."

Up to 120 job loses at Costain

Up to 120 jobs are to go as Costain attempts to cut costs over the next year by \$15.9m. The 30% reduction in costs will necessitate the merger of Costain's Construction & Civil engineering divisions in the UK. The

economic downturn in South East Asia has played a significant part in the company's performance and the contractor has elected to leave Indonesia and minimise operations in Malaysia.

VAT for Øresund

The Danish and Swedish authorities have determined that the future toll fees on the Øresund Fixed Link will be liable to VAT. This decision will negatively affect Øresundskonsortiet's finances because the tax cannot be transferred to the link's users; fares on the ferries are not liable to VAT. Speaking on this subject, Øresundskonsortiet's finance director, Teddy Jacobsen said, "This will reduce the dividend to be paid to our parent companies which, in turn, will have a negative impact on their results."

Trenchless acquisition

UK construction and civil engineering group Pochin has acquired Welsh-based Avoidatrench Ltd and its subsidiary companies for \$3.2m in cash with deferred consideration of up to a further \$1.6m. Avoidatrench specialises in trenchless technology by operating directional drilling rigs in the UK. Nick Pochin, chairman of Pochin, comments, "The group's expertise in the management of its concrete pumping business complements Avoidatrench's existing management, and the group's depot infrastructure will support a gradual expansion of Avoidatrench's operations."

Water exhibition

The organisers of the UK's Iwex '99 international water exhibition claim a 20% increase in stand sales over the last Iwex exhibition in 1997.

Exhibitors at the show will include: Durapipe; S&LP; Essig Products; Johnston Pipes; McNicholas; Putzmeister; Severn Trent International; Tarmac; and VIP Heinke.

The event, which is sponsored and supported by the Pipeline Industries Guild, British Water and the Society of British Water Industries, will be held on October 19-21 at the National Exhibition Centre in Birmingham, UK.

For more details telephone: +44 1895 454540.

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Alastair R Biggart, Vice President, Hatch Mott

MacDonald, charts the immense changes that have affected our industry during the lifetime of Tunnels & Tunnelling International. Although the revolution has been gradual, it has none the less been dramatic as far as the technology is concerned, and ways of doing business are very different compared to 1969

A quiet revolution

First and foremost I should record the thanks of the industry to T&I's editors and staff, ably advised and supported by their advisory board, for faithfully recording the events in the tunnelling industry throughout the world over the last 30 years. This period has been a time of great significance in terms of technological advance, political change, ways of doing business and size and type of companies.

Some of the advances in technology, practice and achievements have been dramatic. Tunnels are being built today where they could not have been attempted 30 years ago. Gigantic caverns are being constructed by new techniques. Lining methods have advanced dramatically, as have ways of improving the ground. Tunnels are being built through ground where water pressures are too high for compressed air and longer tunnels are being constructed at greater depths - all against a background of greater environmental restraint, assistance (and restraints) from quality assurance (QA), a greater awareness of safety needs and an ever increasing number of codes to comply with.

Client expectations are changing, the role of the consulting engineer has altered and there are all sorts of new ways of doing business with confusing acronyms to describe them, like D&B, DBFO, BOOT & BOT.

In the good old, bad old days, the consultant (the Engineer) was king. The consultant designed the facility and then supervised the construction with very comprehensive delegated powers from the owner. Now we have the engineering management consultant, the programme management team, the con-

struction management team, etc. The debate as to whether this is an improvement or not could go on a long time, and maybe it will come full circle.

Other new and improved ways of doing business include partnering and the increase of disputes review boards to replace costly and time-consuming arbitration. In addition, there are more international tunnelling conferences and a number of excellent tunnelling journals, not forgetting the management and technical courses that are organised. However, where we must try and stem the tide of change is in the ever increasing use of lawyers, the abdication of management responsibility to auditors and others who are not involved in the day-to-day business of tunnelling.

Major tunnels built in the last 30 years

The chart (Fig 1) gives the chronology of some of the most significant tunnel projects. It includes tunnels in all the categories listed in the panel (above, right). Some of these tunnels could not have been built safely without the technological improvements developed over the last 30 years. In this category are: the Channel Tunnel, the Trans-Tokyo Bay Highway Tunnel; the Storebaelt Rail Tunnel, Denmark; the St Clair River Tunnel on the US/Canadian border; the Fourth Elbe Road Tunnel in Germany; and the still to be built Niagara Diversion Tunnel in Canada. These tunnels have a common feature: the use of either closed or open face, large diameter TBMs. The tunnel under the Oude Maas is included in the chart as it is the first major tunnel to be driven by TBM in The Netherlands.

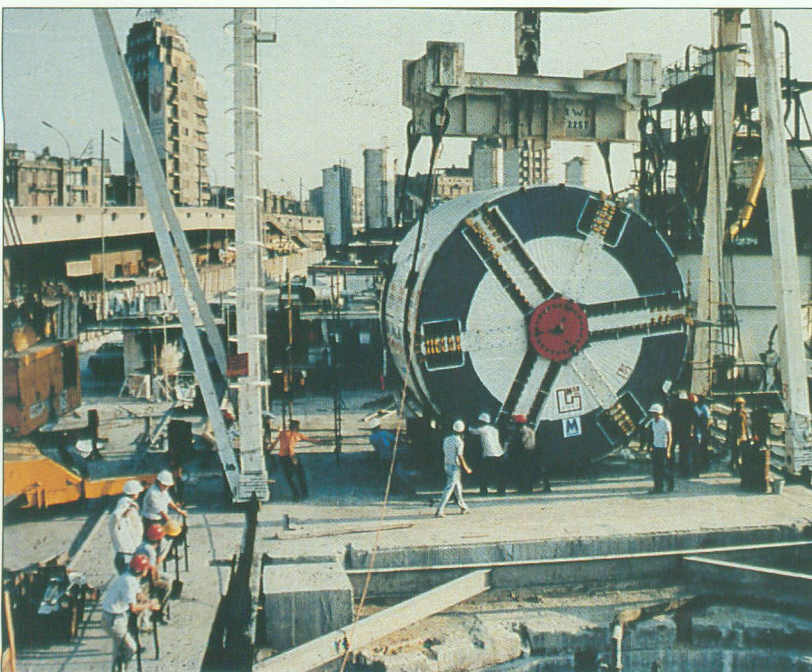
New tunnel companies

It would be wrong to omit those who design and build the tunnels. Thirty years ago, the companies were generally smaller; many of them were still private, unquoted companies; they were national as opposed to international; and they generally carried out smaller contracts. Today, most of the specialist tunnelling companies have been taken over by larger contracting groups, many of whom are international and are capable of taking on very large works.

It is becoming much more common for companies to engage in joint ventures in order to share risk on difficult projects. One could, of course, debate the advantages to the industry of takeover bids - especially hostile ones. But it has to be recognised that with new technology allowing ever more difficult projects to be tackled, owners are seeking contractors with enough financial muscle to shoulder the risks involved.

There has also been considerable change in consulting engineering practices. The small practice of yesterday is the mega international practice of today. Mott MacDonald, for example, was about 400 strong in 1969 and today is 4500. Growth within consulting practices has often come about through mergers and acquisitions. Many consultants who were specialists

One of the slurry machines used on the Cairo Wastewater Project



Uses for tunnels

Around 30 years ago, tunnels were constructed in London and elsewhere for telephone cables. With the introduction of fibre optic cables this need has disappeared. Tunnels are mainly used today for power cables; hydroelectric power; water transport; sewers; metros; railways; and roads. There have, in addition, been some one-off

projects for atomic research, such as CERN in France/Switzerland and the Super Conductor Super Collider project in the US, which was eventually abandoned.

Virtually all tunnels over this period have been constructed to improve the infrastructure. There has been a dramatic increase in the building of sewers as the population of cities has grown, mainly to replace decaying structures and to build interceptors and the necessary outfalls.

Some of these improvements are the results of international pollution control agreements.

Construction of hydroelectric tunnels has continued. However, building metros has increased dramatically as a result of the congestion and pollution produced by the world's huge conurbations and because they are often regarded as status symbols in the developing world. Rail and road tunnels have produced some of the more dramatic examples of significant tunnel projects.

30 years ago have been forced to diversify to survive.

Changes in technology

Although a quiet one, the revolution has been profound. It can be described under six general headings:

- Tunnel boring machines (TBMs)
- The New Austrian Tunnelling Method (NATM)
- Ground improvement
- Tunnel linings
- Tunnelling methods
- Technological improvement

Tunnel boring machines

The advent of closed face TBMs has brought about a fundamental change. Before John Bartlett took out his patent for the Bentonite Tunnelling Machine in England in 1964, TBMs could only be used in ground that was self supporting in the short term, i.e. in rock and cohesive soils. The 1964 patent started a revolution.

The Japanese began experimenting with slurry machines in the mid-1960s, the British in the early 1970s and the Germans with the Hydroschild, also in the early '70s. This led to a spate of tunnels being constructed with slurry machines, especially in Japan, where

infrastructure was badly needed. Hamburg was the scene of most of the early developments in Germany.

Limitations to the method were soon established, the restrictions being generally in the range of ground conditions that could be tackled. At one end of the scale, clay was a problem due to the difficulties of cleaning the slurry. At the other end are boulders. Developments with the cleaning and crushing process expanded the range of ground to be tackled, but not enough to satisfy the variety of ground to be excavated. (The photograph on p18 shows one of the slurry machines used on the Cairo Wastewater Project.) So, in the mid-1970s, the Japanese came up with the earth pressure balance machine (EPBM) concept, which significantly broadened the range.

In essence, a slurry machine supports the tunnel face with a clay slurry and uses the slurry as a transport medium to take away the spoil as a 70/30 slurry/solids mix. An EPBM supports the face by holding the excavated material in the plenum chamber, adding up to 30% liquid conditioner and controlling the face pressure by variable use of a screw conveyor. Some manufacturers now make TBMs that can be used both as slurry machines or EPBMs.

“Tunnels are being built today where they could not have been attempted 30 years ago”

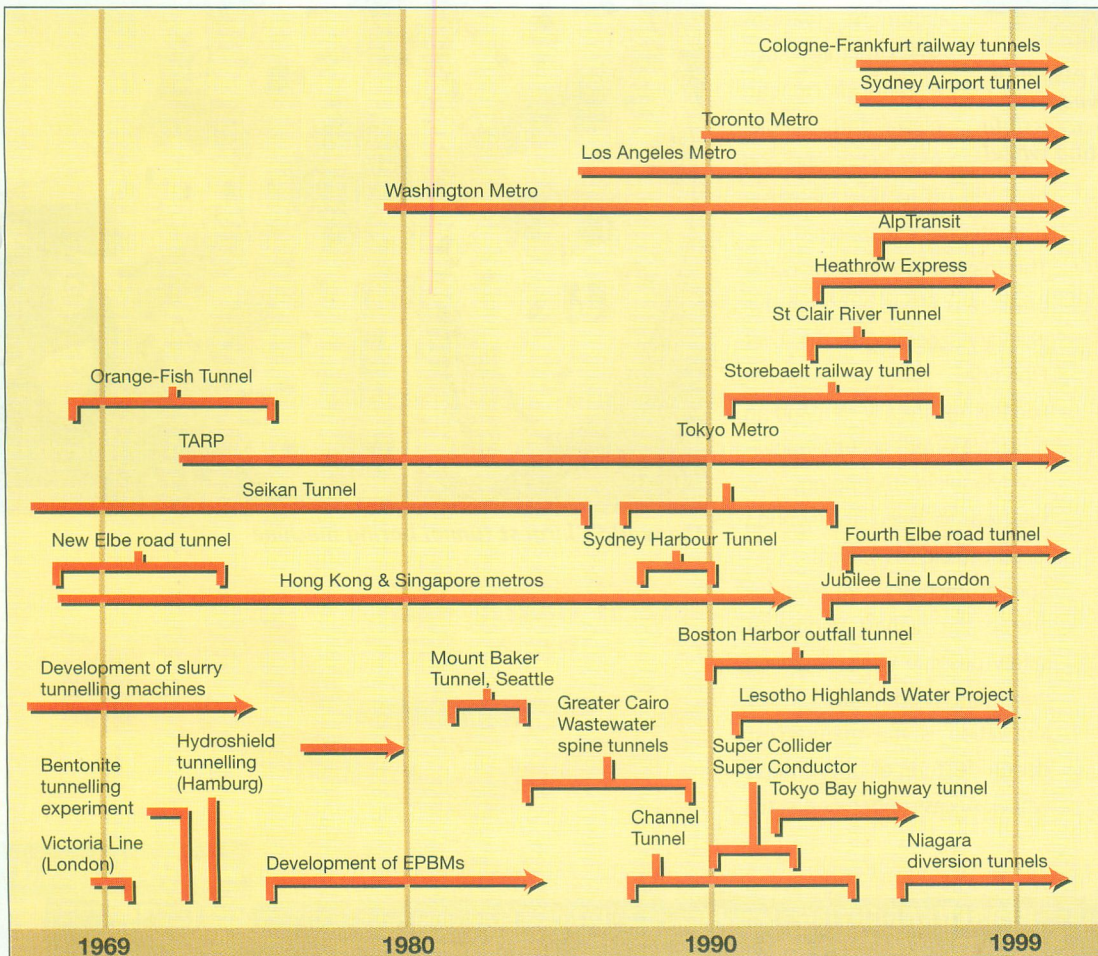


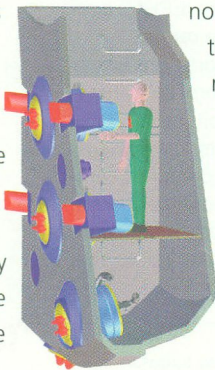
Fig 1. Chronology of some of the most significant tunnelling projects of the last 30 years

High-Tech-Tunnelling Underneath The Elbe

The "Fourth Elbetunnel"-project in Hamburg, Germany, is very demanding due to extremely geological features, very high safety requirements and an enormous tunnel diameter.

Even though the work has to be done under hard and difficult conditions, the Herrenknecht Mixshield has already crossed under the majority of the river Elbe. By the middle of April more than 1.400m of the 14.20m diameter tunnel has been achieved.

A 950m long section of the tunnel must be driven under the busy river Elbe. This must be carried out without causing any disturbance to the shipping traffic. At the most difficult point, the soil coverage is limited to only seven



An essential requirement is the accessible cutting wheel

meters. Already the machine has successfully completed a section where the soil coverage was limited to 11 meters. Where the tunnel passes under the

northern Elbe slope, there is an exclusive residential area, here the tunnel passes under houses with a minimum distance of only 9,5m to the floor of the cellars. Along the tunnel alignment, various soil structures such as sand, silt cement, glacial drift, shingle, mica silt, stone and boulders up to two meters in diameter are encountered.

The maximum expected water pressure is 6 bar, although this will vary according to the River Elbe tides.

For this technically demanding project, Herrenknecht's innovative Mixshield technology was selected to build the world's largest shield (ø14,20m).

Special technical innovations ensure the highest degree of safety possible whilst enabling maximum productivity. A key innovation is the man access design feature of the cutting wheel. Access under air pressure is possible into each of the five spokes of the cutting wheel through individual airlocks. This enables cutting tool maintenance to be carried out safely on the cutting wheel regardless of the high ground water conditions. This feature has proven effective several times on the project to date.



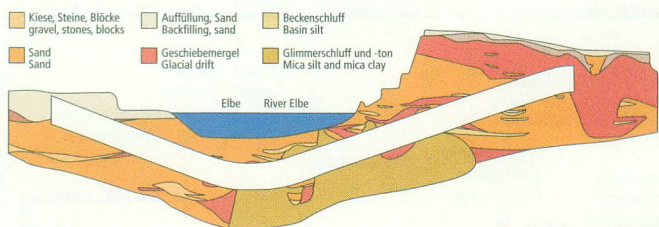
Active center cutter



High-tech tunnelling deep under the busy river Elbe



The world's largest tunnel boring machine



Data & Facts

Tunnelling project

Fourth tube of the Elbtunnel (road tunnel)

Project owner

Federal Republic of Germany, represented by the Free Hansa City of Hamburg

Client

Bilfinger + Berger Bau AG, Dyckerhoff & Widmann AG, Heitkamp GmbH, Hochtief AG, Philipp Holzmann AG, Wayss & Freytag AG, Ed. Züblin AG

Tunnelling Machine Data

Machine type: Mixshield, ø 14.20m
Weight: 2,600to
Length: approx. 60m
Connected load: 6.5MVA

The other significant advance is size. Up to 1969, TBMs over 10m diameter were very rare. Today, that figure is over 14m diameter for closed face TBMs and over 12m diameter for rock TBMs. The photograph (right) shows the 14.2m diameter slurry TBM being used on the Fourth Elbe Road Tunnel in Germany.

The advent of closed face TBMs has had a considerable effect in reducing the use of compressed air working, first introduced in the 1880s.

Ground improvement

Today, the tunneller has many tools at his disposal for improving ground conditions in both rock and soft ground. Most of the methods were not invented during the last 30 years, but they have all been significantly improved::

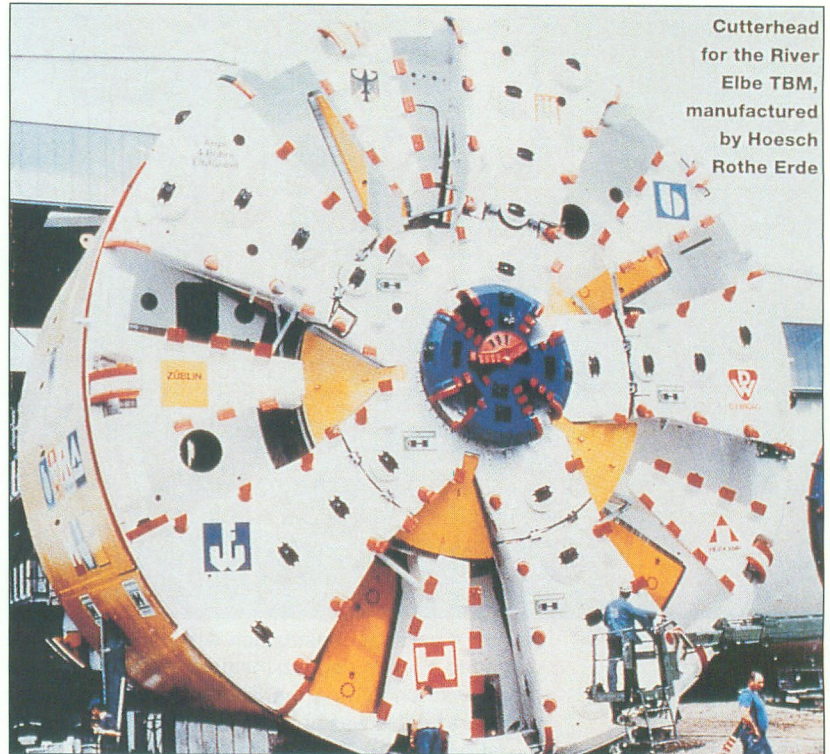
- Ground freezing
- Compressed air
- Grouting
- Dewatering
- Jet grouting
- Deep mixing
- Diaphragm walls/cut off walls
- Rock bolting/spiles

The skill employed by geotechnical engineers in applying the methods mentioned above to help the tunnellers is crucial on some projects. A typical example was the Storebaelt tunnel, where five out of the eight methods were used.

Ground freezing has existed for a long time. The last 30 years have not seen significant change, except in the ability to measure and monitor what is happening in the ground. The equipment has also improved considerably. The photograph on p22 shows ground freezing for cross passage construction on Storebaelt.

The use of compressed air has been reduced during the period, largely because of the development of slurry machines and EPBMs. At the same time, knowledge on how to use compressed air safely has improved. Better decompression tables have evolved which reduce the risk of decompression sickness and allow greater understanding of bone necrosis.

Grouting is a very broad subject and difficult to cover in a few words. Since 1969, more cement/ben-



Cutterhead for the River Elbe TBM, manufactured by Hoesch Rothe Erde

tonite is being used. Compensation grouting has been employed extensively and more scientifically. The use of materials like microfine cement, various silicate combinations, resins and polyurethane has increased. Some materials have been banned due to greater environmental awareness. The introduction of tubes-a-manchette selective grouting has improved the precision and predictability of the method.

The use of dewatering has become more scientific and the equipment is much improved. A dramatic use of dewatering techniques occurred on Storebaelt, where local vacuum assisted well points were used

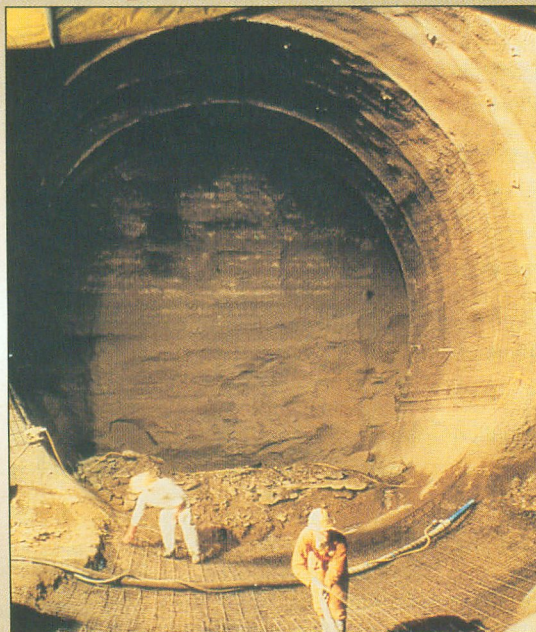
The New Austrian Tunnelling Method (NATM)

Let us for the moment forget the controversy about who invented NATM. The method has truly been a development of the last 30 years and is a useful addition to the tunneller's armoury. The photograph on the right shows one of the large caverns constructed for the Channel Tunnel using NATM.

The definition of NATM is fraught with difficulties. It concerns in part the use of flexible materials (shotcrete, lattice girders, rockbolts) which act in unison with the ground around the structure. This technology is combined with observational techniques which are used to confirm that the ground and lining behaviour is as predicted, allowing adjustment by extra rockbolts or extra shotcrete if the behaviour differs from expectations.

The controversy will continue, but let us all recognise that NATM is a useful tunnelling technique if it is employed in the right ground conditions with extra special care.

NATM has now been used on a large number of significant projects with great success, although, unfortunately, everyone tends to talk about the failures, which have usually been dramatic. However, it is not the method that is to blame but usually human error.

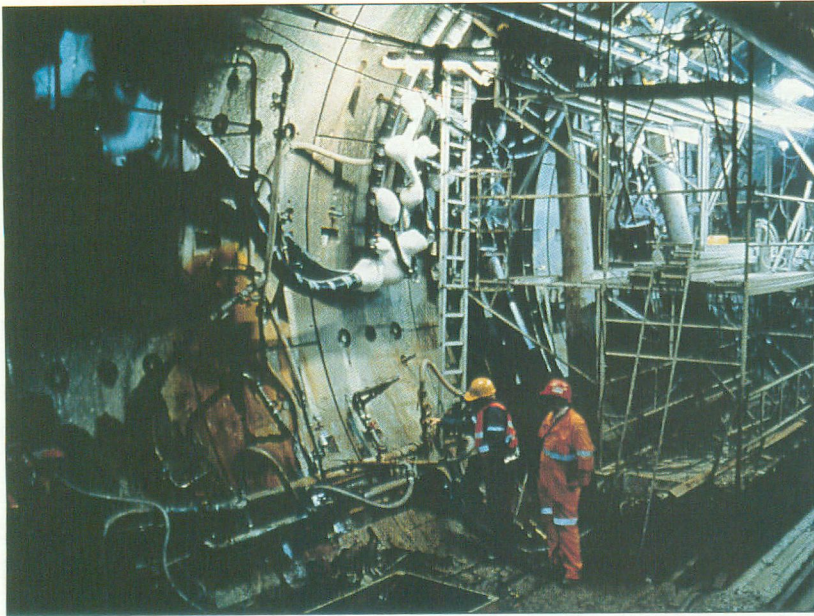


One of the large caverns constructed for the Channel Tunnel by means of the NATM

“NATM has been used on a large number of significant projects with great success, although everyone tends to talk about the failures”



Ground freezing under way for cross passage construction on the Storebaelt Tunnel in Denmark



for cross passage construction. Also, deep wells were drilled to a 100m depth beneath the seabed into the chalk marl underlying the tills to reduce pore water pressures. This was aptly named 'Project Moses'.

Jet grouting was introduced in the 1970s. Like all ground improvement methods, it has to be used in suitable ground. The essence of this method is ground replacement combined with improvement. It was extended to horizontal applications in the 1980s.

The diaphragm wall technique was introduced in Italy in the 1950s and has been extensively used throughout the last 30 years. The technique has not changed much, although the understanding of its limitations has been enhanced. A development of the method involves its use for non-structural cut-off walls, an application was used by the French to seal their

50m diameter working shaft on the Channel Tunnel.

Rockbolting has become very much more scientific, with a large variety of methods, including simple grouted-in steel rods using cementitious grout; resin grouted rock anchors; and hollow steel tubes which are expanded within the predrilled hole. The method is used to bolt the rock for increased strength, to anchor the surface of the rock to prevent heavy spalling or to act as shear dowels within the rock mass. It is employed as traditional rock tunnel support in combination with heavy mesh or plates and is also used as part of the NATM process. Forward spiling, although different from rockbolting, is used to give temporary greater shear resistance to the ground at the face.

Tunnel lining

Soft ground tunnels around the world today are being lined by one pass linings, i.e. a high quality bolted precast concrete ring. Thirty years ago, much greater use was made of cast iron. The improvements during the period are related to segment design, bolting methods and, very importantly, gasket sealing methods. Resin coated reinforcement is now employed for greater durability. Expanded unbolted lining has seen more use, most notably on the UK side of the Channel Tunnel. Because of the better sealing systems, based on compressible neoprene seals (introduced in Germany in the 1970s), segmentally lined tunnels are being built to resist groundwater pressures up to 15 bar. Another recent step forward is the use of a one pass segmental lining for rock tunnels, as employed on the Lesotho Highlands Water Project.

Conclusion


The last 30 years have been an interesting time for tunnelling and for tunnellers. The most significant developments of the three decades for me are:

- Development of slurry machines and EPBMs
- Introduction of very large TBMs
- The rise of NATM (but not the fall!)
- The use of computers for almost every aspect of construction and tunnelling

It has not always been an easy period for the industry. Work has come in feast and famine fashion - high inflationary times have damaged the industry and there has been constant change in codes, regulations, safety legislation and QA requirements. The political and environmental climate is difficult and the major players in the industry have changed dramatically. Bureaucracy has taken hold in many areas, interfering with our ability to get things done in a timely fashion.

On the positive side, we have a great array of useful new and equipment at our disposal and we can construct tunnels in increasingly difficult ground conditions.

What will we be doing for the next 30 years? Owners must be persuaded that it is important to preserve our skills base and keep letting out new work. In the UK, this includes Phase 2 of the Channel Tunnel Rail Link and CrossRail in London. More money needs to be allocated by governments for research: this is a cry that has gone largely unheeded over the last 30 years.

But we, the tunnellers, must get out there and sell tunnels as appropriate solutions for infrastructure and environmental improvement. The modern age may not be set to produce a Brunel but we can create great teams to build magnificent works: some of the examples of the last 30 years should leave us justly proud of our achievements. I, for one, have enjoyed the challenges and look forward to seeing what the future holds for all of us. In the meantime, Happy Birthday *Tunnels & Tunnelling International!* 

Tunnelling methods

So what, in summary, are the new tunnelling methods introduced during the last 30 years and what related improvements in technology have assisted with the use of these methods?

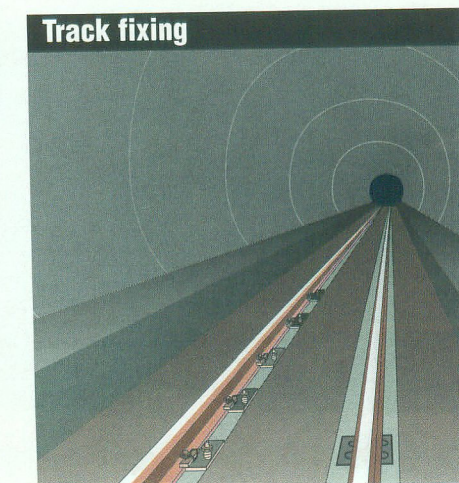
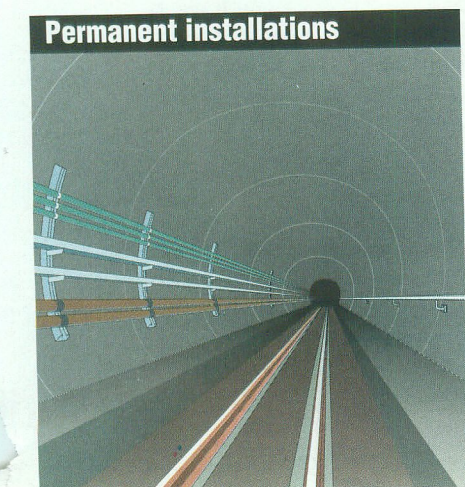
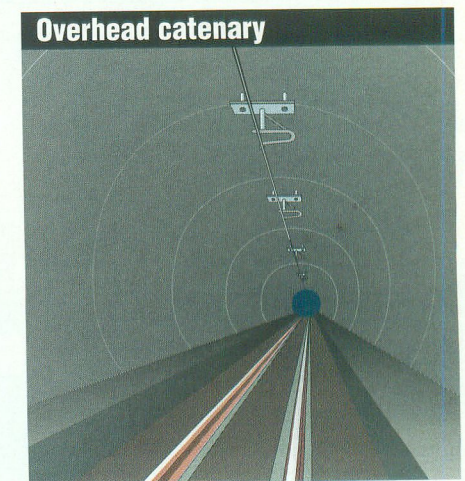
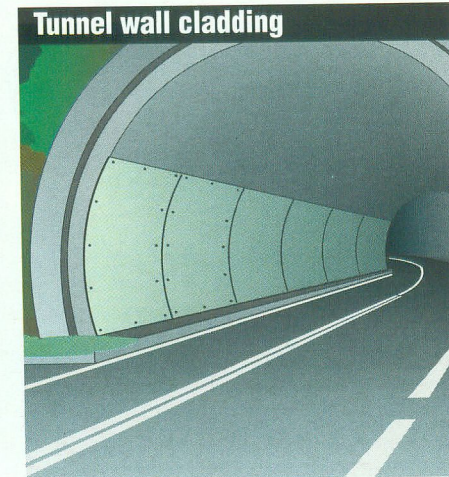
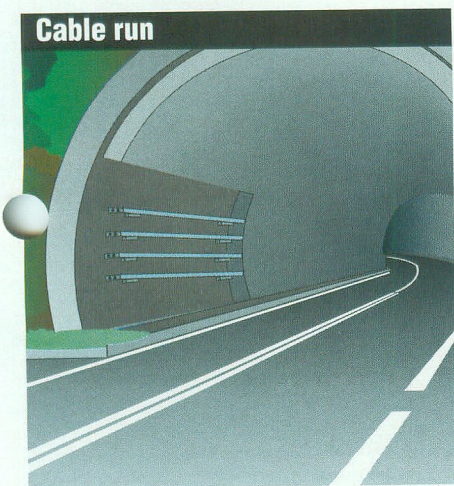
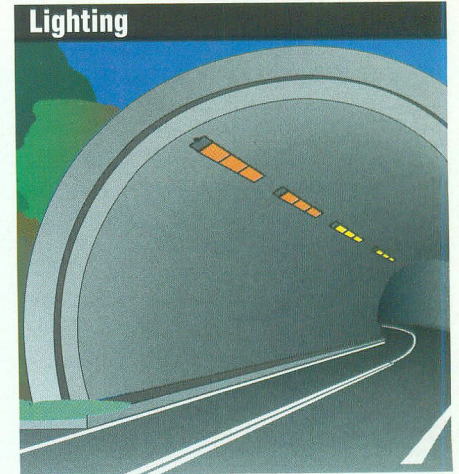
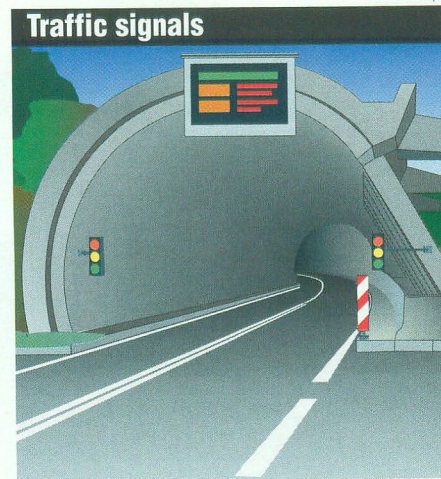
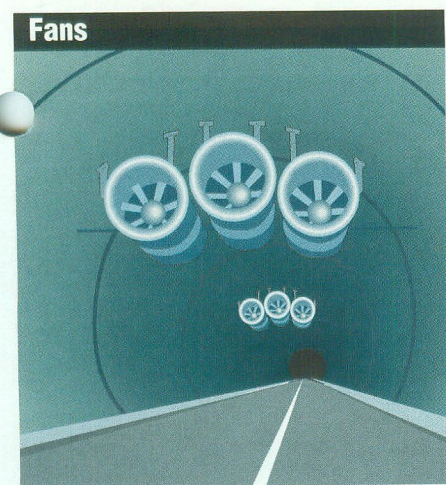
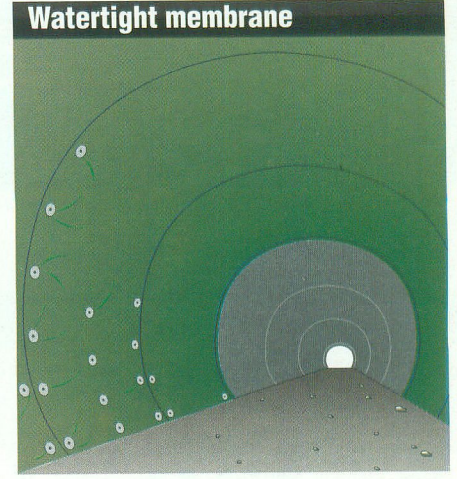
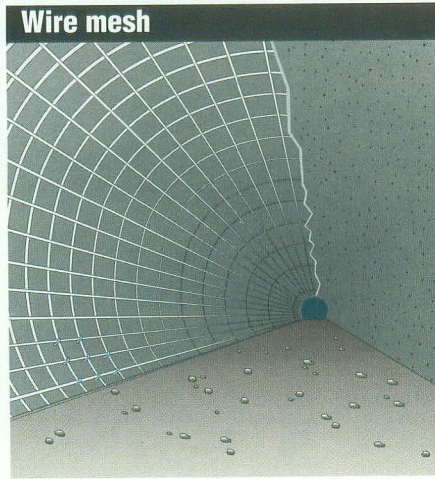
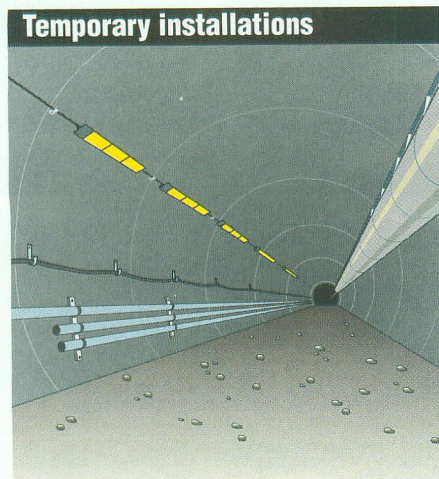
New methods include:

- Precutting the arch and filling with concrete ahead of the tunnel face
- Multiple connected drifts and large caverns, used for the Mount Baker Ridge Tunnel, Seattle and on the French crossover cavern constructed for the Channel Tunnel
- NATM
- Closed face TBMs and diminution of the use of compressed air
- The introduction of very large TBMs
- Hydraulic rock drills replacing pneumatic drills
- The use of roadheaders for excavation, introduced in civil engineering in the early 1970s
- Increased use of pipejacking for

longer lengths and bigger diameters

- Introduction of microtunnelling
- Improved raiseboring equipment
- New ground treatment methods
- Improved and greater use of one pass linings
- Technology Improvement
- Major leap forward in surveying equipment
- Use of GPS for survey
- Use of lasers for tunnel guidance
- Introduction of computer systems such as ZED instruments for tunnel guidance
- Electronic/computer controlled instrumentation for TBM operation and diagnostic maintenance
- Improved welding technology
- Improved range of disc and pick cutters for TBMs
- Much improved back-up equipment, such as cranes, locos, concrete cars, etc
- Better ventilation technology

Hilti fastening technology in tunnel construction



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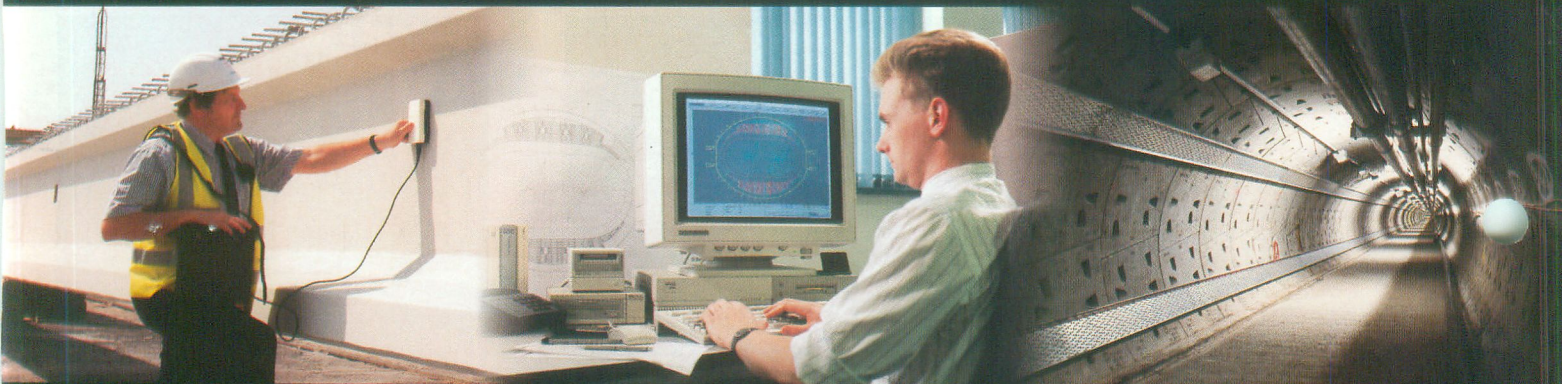
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The investigation and planning procedures for the 5.3km long, 160m deep Frøya sub-sea tunnel in Norway are described by Kristin Hilde Holmøy, Engineering Geologist, O T Blindheim; Jon E Lien, Project Manager, Norwegian Public Roads Administration; and Arild Palmström, Norconsult. The area has been exposed to complex faulting, resulting in extreme tunnelling conditions. Special precautions, extensive investigations and measures for quality control have been taken to ensure that the project is finished to time and budget.

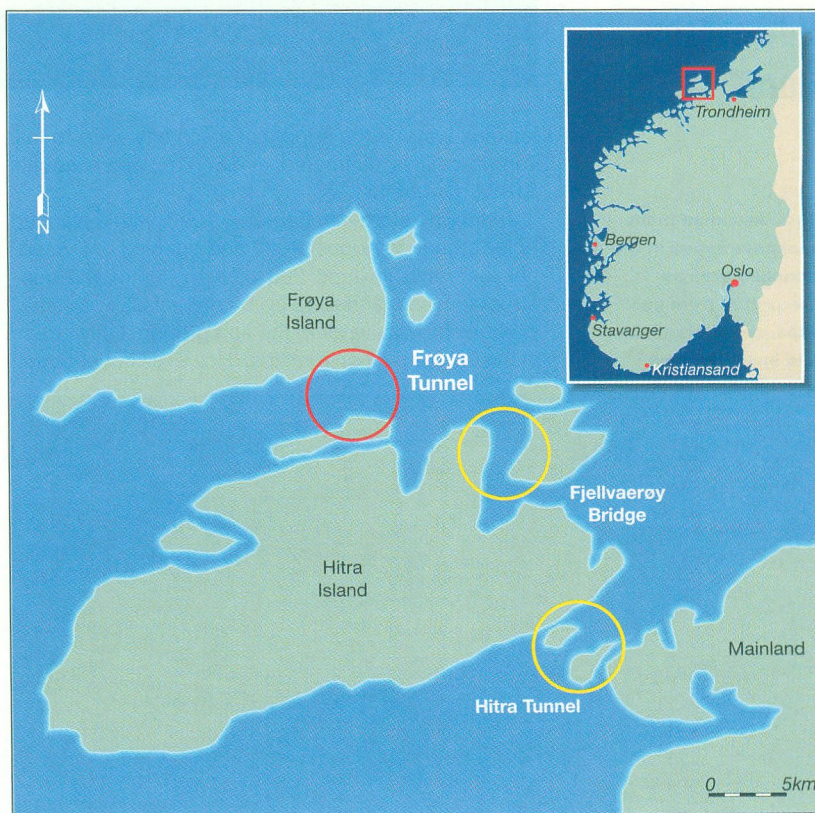
Going sub-sea on the brink of the continental shelf

The Frøya sub-sea tunnel is currently under construction on the north-west coast of Norway (Fig 1). Around 30 previous sub-sea rock tunnels along Norway's coastline have yielded valuable information during the planning stages of this tunnel, which is the second sub-sea tunnel in the Hitra-Frøya project.

Pre-investigations for both tunnels started in 1982, and for the Frøya Tunnel continued more or less until construction started in early February 1998^{1,3}. Compared to other, similar projects, very comprehensive investigations were carried out, which revealed complicated and, in some cases, uncertain geological conditions. Challenging tunnelling conditions were therefore anticipated, with several large, probably difficult, weakness zones to pass through, and, in addition, the possibility of encountering young, sedimentary rocks.

The Frøya Tunnel is the final leg of the Hitra and Frøya Mainland Fixed Link. The project completes a scheme by the Ministry of Transport & Communications to replace ferries and improve access to the national road network and boost a flourishing local fish farming industry on the largely barren islands of Hitra and Frøya off the Trøndelag coast. The project is part of public policy in Norway to provide infrastructure to outlying areas, a development strategy known as the 'District Policy', which is based on a broad political agreement to preserve traditional population patterns in the country.

The entire package, comprising two tunnels, bridges and roads, is estimated at a total of \$124.5m. The enterprise started with the bridge connection to the small island of Fjellvaerøy, east of Hitra, in 1990, which was completed in 1992. It was followed by what is claimed to be the world's deepest road tunnel - between mainland Norway and Hitra - finished in December 1994. Excavation of the Frøya Tunnel is about three quarters of the way through and is almost eight months ahead of schedule, with commissioning predicted for mid-2000.



Selmer ASA is the main tunnelling contractor and the project is jointly funded by national and local government grants and toll charges.

The Frøya Tunnel

The Frøya Tunnel is 5.3km long, with its deepest point 160m below sea level. The major portion is under the sea (3.6km), where the rock overburden varies between 37m and 155m. The two-lane tunnel has cross sectional area of 50m² (T8 tunnel profile). Maximum gradient is 10%.

A reservoir of 1150m³ was to be excavated at the lowest point, large enough to store four days' worth of

Fig 1. Location of the Frøya Tunnel between the islands of Hitra and Frøya off the north west coast of Norway

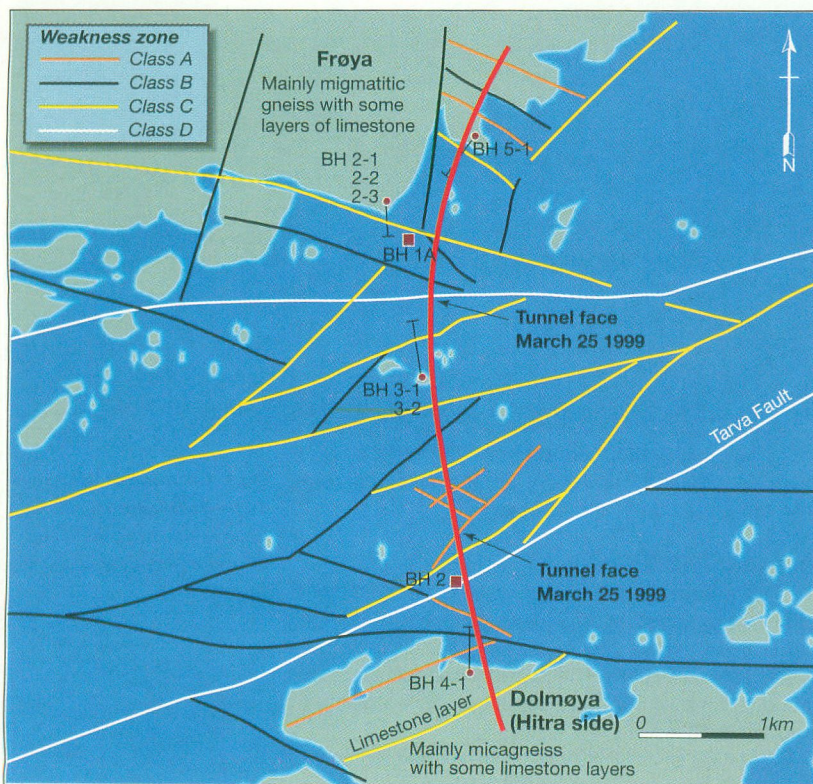
Work under way in the Tarva Fault (Class D zone), a main geological feature which runs for more than 150km NW on the Norwegian mainland

“Unexpected, exceptionally poor, ground conditions were discovered on the northern side of Frøy Fjord”



leakage water if the supply of electricity were to fail. Tunnel cost is estimated at \$54.7m, which equals \$1032/m of tunnel.

Fig 2. Assumed main weakness zones in the tunnelled area as interpreted from geological maps, aerial photos and field investigations



Tunnelling started in February 1998, with a planned hole-through in August 2000 and opening of the tunnel for traffic in June 2001. Nearly all of the constructed was planned to be by drill+blast, with small portions by excavator in the soft ground. Only 1.6km in the middle section remains. However, construction

is eight months ahead of schedule and the tunnel might be opened in the summer of 2000.

Geology

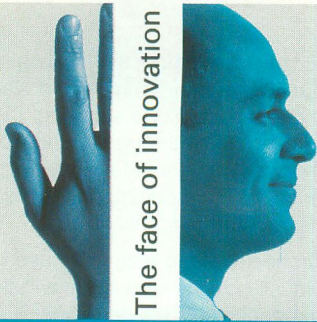
The geology comprises metamorphic rocks of Precambrian age, with gradual transitions between various gneissic rocks such as granitic gneiss, micagneiss, and migmatite. A few bands of limestone/marble have been observed in the actual area. The strike of the rocks is mainly ENE-WSW with a steep dip towards the NW. The area has been exposed to major faulting in the Precambrian age as well as the Caledonian and the Alpine Orogenesis. There are several depressions and valleys representing faults and thrusts. Similarly, the map of the seabed shows topography with marked depressions indicating the presence of faults or other weakness zones. Refraction seismic measurements confirmed this (Fig 2).

A main geological feature is the Tarva Fault (see photograph above), which runs more than 150km NW on the Norwegian mainland. This ancient fault was assumed to be reactivated during the Jurassic/Cretaceous and perhaps also in the Tertiary age.

Field investigations

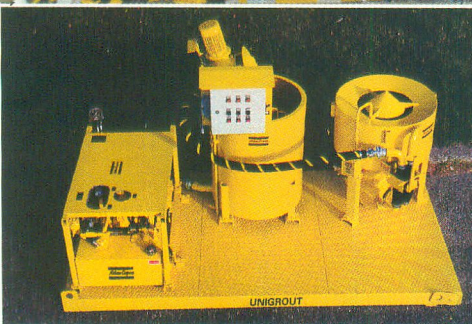
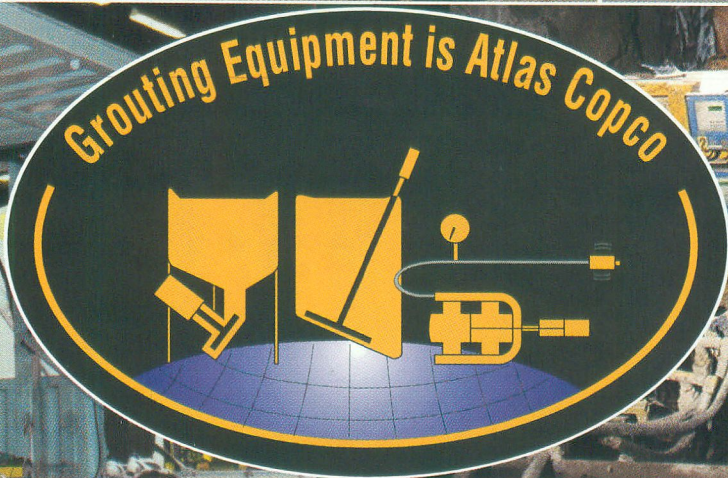
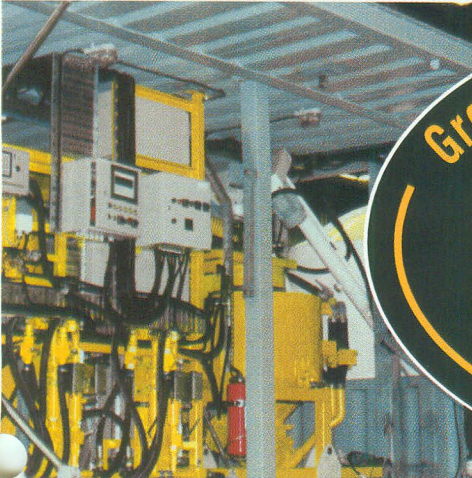
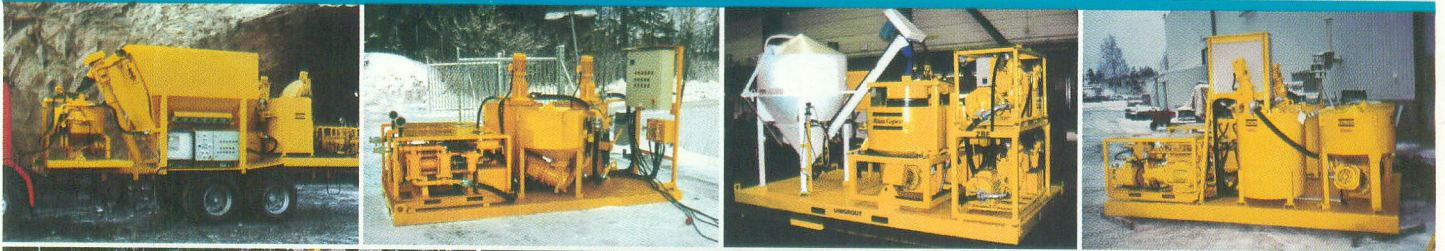
Field investigations started in 1982 with construction of maps, collection of available geological material and initial seismic measurements consisting of shallow reflection seismic (acoustic) measurements and the first refraction seismic profiles. In 1995, during the final design, core drillings were performed from both sides of the Frøy Fjord.

Unexpected, exceptionally poor, ground conditions were discovered on the northern side of the fjord. The tunnel alignment was adjusted to the east in this section, where the following additional field investigations were performed:



The face of innovation

Grouting

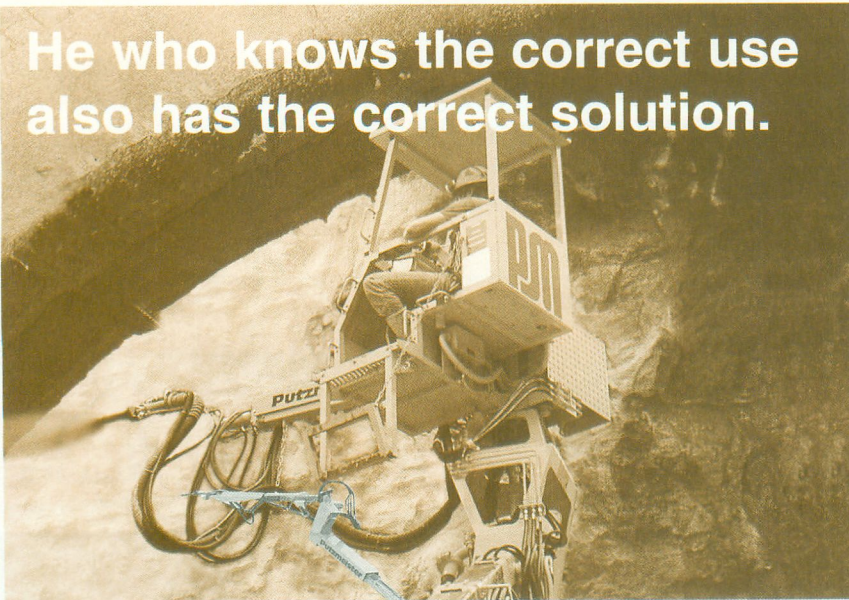


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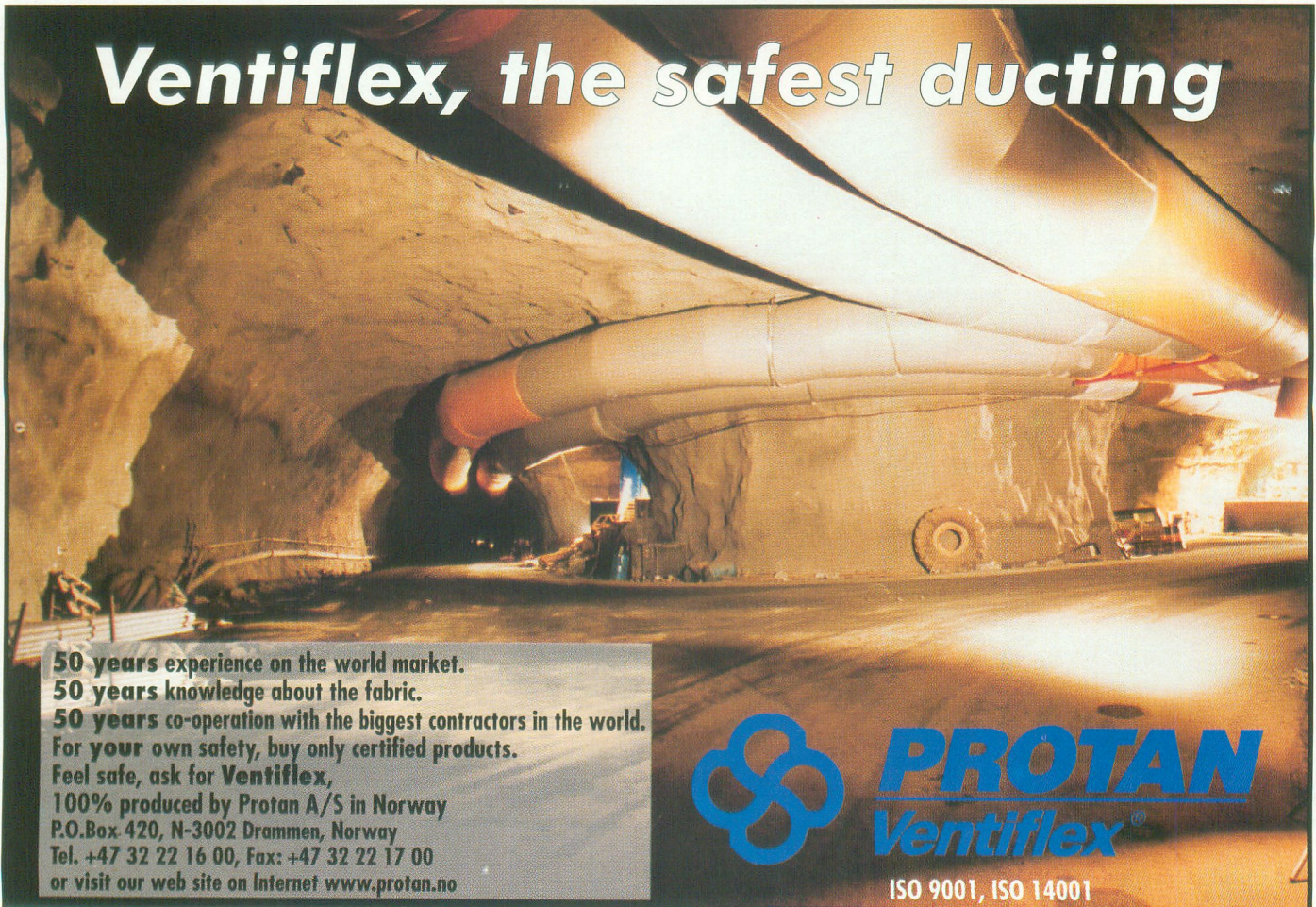
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The Atlas Copco computer assisted Rocket Boomer 353S drilling jumbo at work on the Frøya Tunnel

Fig 3. Tunnelling progress to March 22 1999. 70% of the tunnel had been excavated and many difficult zones had been successfully negotiated. Tunnelling is eight months ahead of schedule

- Refraction seismic profiles along the tunnel alignment with several cross profiles

- Inclined core drillings from the land and from small islets in the Frøy Fjord. There were many drilling problems caused by the difficult ground conditions:

- Two drill holes in the fjord from a drill ship
- Special studies of the tectonic setting in the region

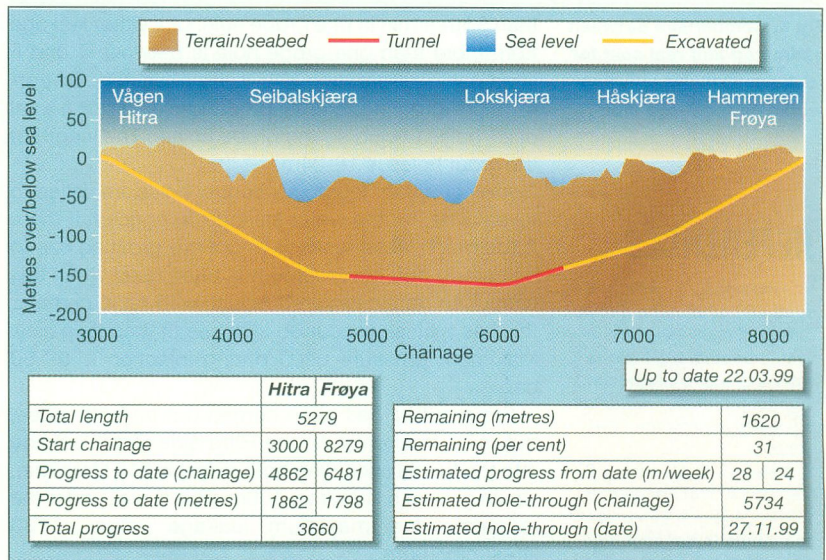
- Detailed core logging and laboratory testing

The refraction seismic measurements have shown more low velocity (weakness) zones than in any of the other sub-sea tunnels constructed in Norway. The material in many zones consists of clay, silt, sand and gravel. Often, the clay shows a high degree of swelling, having low strength and friction properties. In total, 10 500m of refraction seismic profiles and 1747m of core drilling were carried out. Before the final decision to build the tunnel was taken, two groups of engineering geology experts performed feasibility, risk and cost evaluations.

Feasibility and cost evaluations

Both reports concluded that the tunnel could be constructed within justifiable economic limits using drill+blast, provided that there was thorough quality control during planning and construction. The reports divided the ground into different classes based on a detailed prognosis of expected ground conditions. For each class, the appropriate types and amount of rock support were given. In addition, leakage conditions with a predicted amount of grouting works were assumed along the tunnel.

In the report prepared by Nilsen et al⁵, the ground was divided into eight different classes: four for the expected ground quality between weakness zones; and four for the main types of weakness zones - classes A, B, C and D. Weakness zone Class D is expected to be the worst zone to pass through. There are two Class D zones, one of them the Tarva Fault ,



as shown in the photograph on page 26.

The prognosis has been used to follow up construction time and cost. Fig 5 shows real cost compared to estimated cost.

Results from tunnelling

Probe drilling and pre-grouting: major uncertainties and risks have been, and are, connected with water leakage and unstable, collapsing ground. As part of the quality control, an extensive programme for probe drilling and follow-up of the tunnel works has been implemented. For every 20m of tunnel excavated, three to six exploratory drill holes are being carried out ahead of the working face to gain information on the ground conditions. Below sea level, at least six probe holes at 30m centres are drilled. In this way, the necessary measures can be taken before tunnelling into the difficult ground.

If the probe drilling results in water leakage of more

Fig 4. Basic principles of the probe drilling system. Core drilling is performed where difficult ground is expected

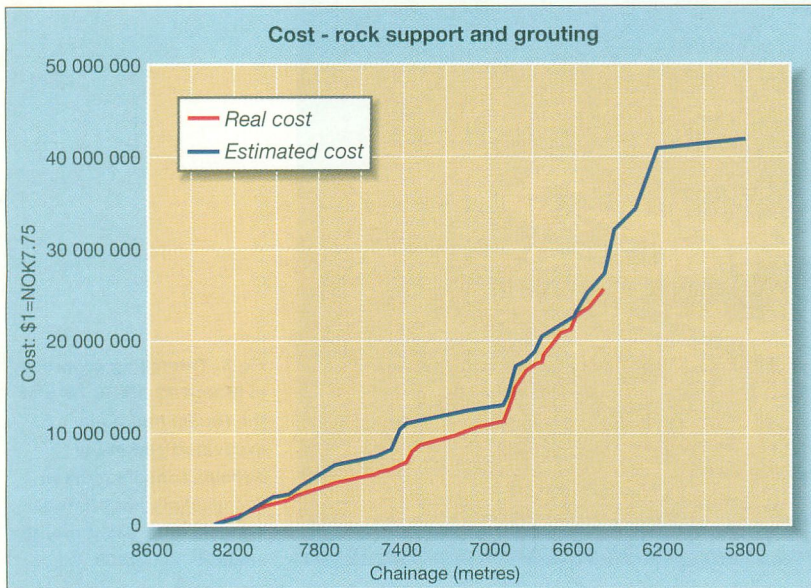
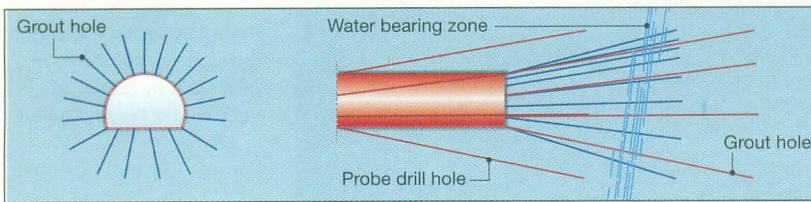


Fig 5. Comparison between estimated and real cost for rock support and grouting works on the Frøya side

than 5 litres/min in one probe hole, or if water leakage from more than one probe hole is between 3 and 5 litres/min, pre-grouting has to be executed. To perform pre-grouting, normal procedure is to drill a total of 21 holes (including the probe holes). The length of the grout holes is 18-24m.

After grouting, four to six control holes are drilled to reveal whether the water leakage is reduced. If there is too much water leakage, more pre-grouting has to be carried out. Microcement is often used when it is difficult to obtain required results with rapid cement; this has typically occurred in zones that contain clay. Maximum pressure used during injection is 50-60 bar.

Pre-grouting has been carried out on both sides, but most frequently on the Hitra side. Total leakage into the tunnel (including both sides) is 310 litres/min, which gives 8.5 litres/min/100m. This is well under the recommended maximum leakage value of 30 litres/min/100m.

Tunnelling through good and weak ground

About 70% of the tunnel has poor to very good ground, with Q-values ranging from 1 to 40. In such ground conditions, normal blast rounds are 5m. The rock support consists of one or two layers of fibre reinforced shotcrete (fibrecrete) 60-120mm thick in the roof and part of the walls, in conjunction with 3m long CT-bolts (fully grouted).

In weakness zones, more thorough measures and rock support are necessary. In addition to probe drilling and occasional grouting, some of the measures taken in difficult ground are:

- Stabilising the ground over and on both sides of the next round by 6m long spiling bolts spaced at 0.3-0.5m
- Using short blasting rounds and spraying fibre-reinforced concrete on roof, walls and face soon after blasting
- Using stepwise excavation and concrete lining in

addition to fibrecrete (above) where stability is very poor.

- Concreting the invert
- Having the equipment available to concrete the face quickly and fully to protect against cave-ins, progressive sliding, etc

- Having high pumping capacity and modern equipment for rock support operating at short notice

To check the stability of the construction, convergence measurements are begun some time after the zones are passed through. Usually the displacement ends after a few months, but in one of the weakness zones the displacement was 17mm and concreting of the invert was carried out to stabilise the movements. The latest measurements show that the concrete invert has slowed down the displacement.

The Tarva Fault is one of two Class D weakness zones. The refraction seismic measurements show a 65m wide zone with a 3km/s velocity. The rock overburden is a minimum of 40m. Probing by core drilling performed from a recess in the tunnel showed that the zone consisted of altered marble, marblebreccia/conglomerate, sandstone, calcite and pegmatite containing clay seams with a thickness of 50mm to 4m. In the middle of the fault there were several places with core loss of 0.5 to 1 m. Tests of the clay at chainage 4444 showed swelling pressure of 0.7MPa.

There was a sharp boundary between good rock conditions (gneiss) and the fault. The weakness zone started with a 4m wide zone consisting mainly of clay. There was no leakage and therefore no problem concerning stability.

Probe drilling at chainage 4469 gave a total water leakage of 59 litres/min in six probe holes. Grouting was necessary in the remaining part of the weakness zone.

Tarva Fault precautions

Approximately 100 tonnes of cement was injected in the Tarva Fault, of which 60 tonnes were microcement. Poor ground conditions (soil-like material), combined with minor leakage, resulted in less stable conditions. The following steps were implemented in tunnelling through the zone:

- Reduced excavation round, only 3m instead of 5m
- 6m long, fully grouted spiling bolts with 0.2-0.4m spacing (36-95 bolts/round). Steel straps and shotcrete are used to fix the outer end of the bolts to the rock
- One or two layers of fibre reinforced shotcrete (fibrecrete) 60 - 120mm thick in roof and walls, immediately after blasting
- 3m long CT-bolts (fully grouted) with average spacing of 1.5m; and
- Two to three layers of fibrecrete, total shotcrete thickness 120- 310mm
- Three reinforced ribs of sprayed concrete
- The floor along the zone was concreted (69m)
- Concrete lining (64m)

In the poorest ground, at chainage 4476-4483, excavation was carried out using an excavator.

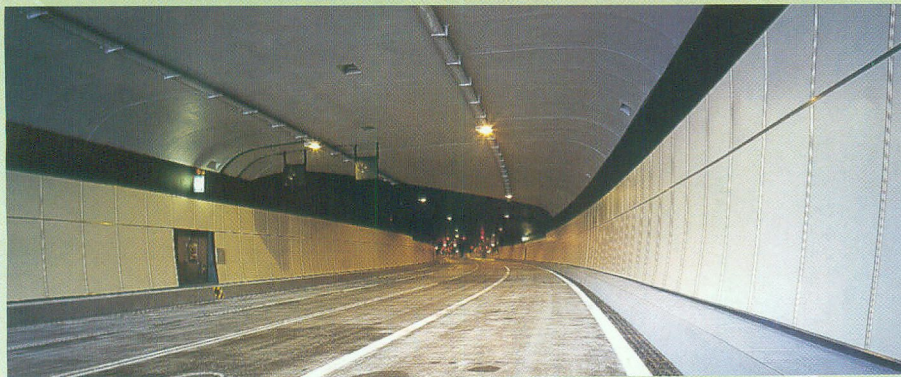
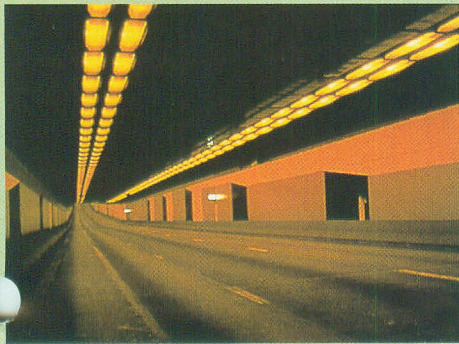
The detailed prediction of expected ground conditions, rock support and construction cost has been used to compare the real cost and the estimated cost for these operations. As shown in Fig 5, the estimated and real costs for rock support and grouting are close. This is also the case for the southern (Hitra) part of the tunnel.

Exchange rate: \$1 = NOK7.75.

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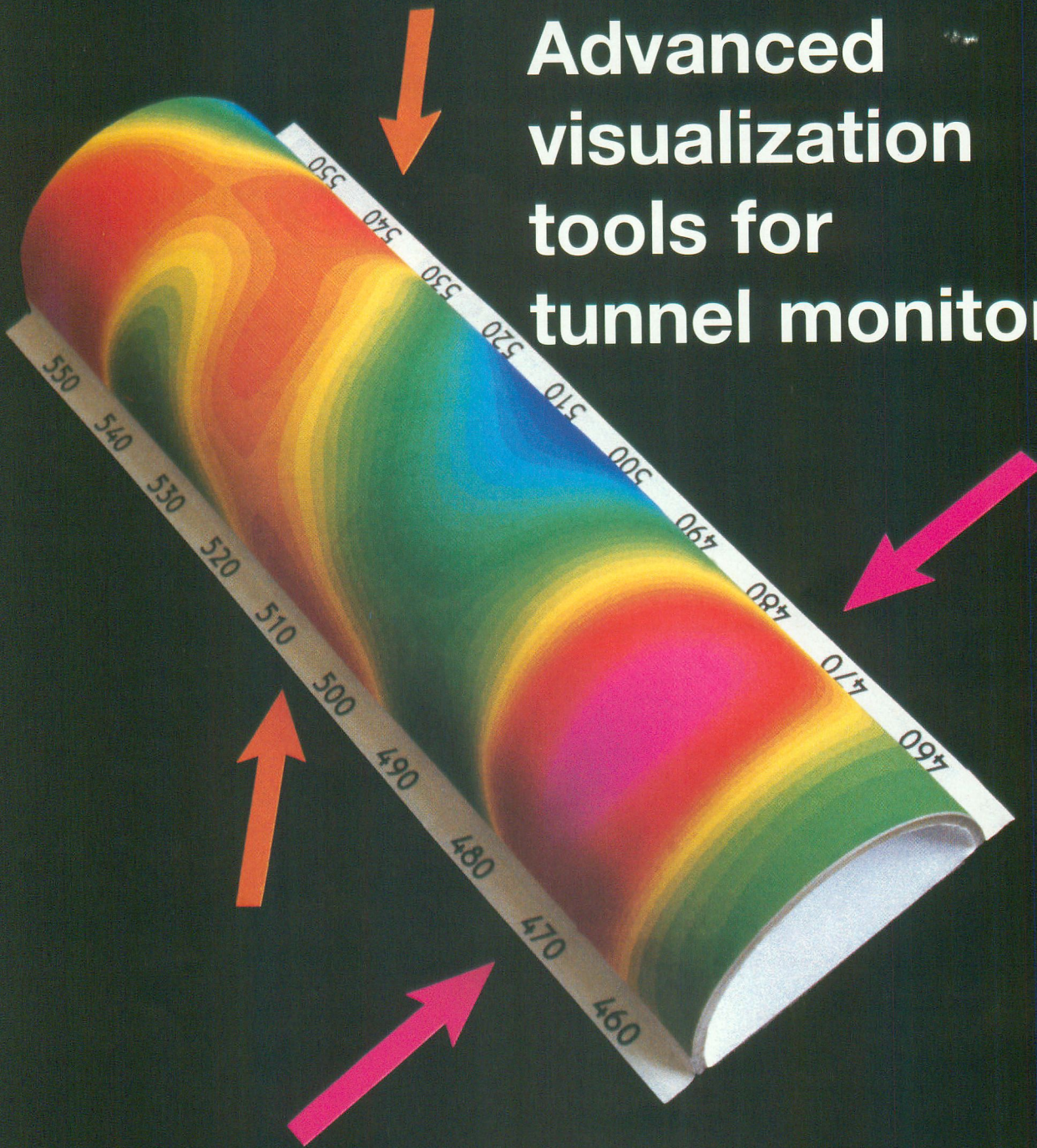


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LEOBEN - AUSTRIA

This new high-speed railway, like the Hannover-Würzburg link, includes a high proportion of tunnelling. Except for a short twin-tube, single-track shield driven tunnel and cut+cover sections, the line's mined tunnels comprise single-tube, double-track NATM operations. Our Special Correspondent Shani Wallis visited the project and sent this report.

Cologne-Frankfurt high-speed railway

Cologne to Frankfurt on the new high-speed railway will be a 58-min, 300km/h, 219km journey with 47 route kilometres passing through 30 tunnels (Fig 1). All the mined tunnels on the main line, similar to the original Hannover-Würzburg high-speed link, are single-tube, double-track excavations and all are designed as multi-drift NATM undertakings.

"The cross section of our tunnels varies from 137m² to 154m² depending on geological conditions," explained Ing. Franz Kapfinger, co-site manager for the Tunnel Montabaur JV when T&T visited the project in late February this year.

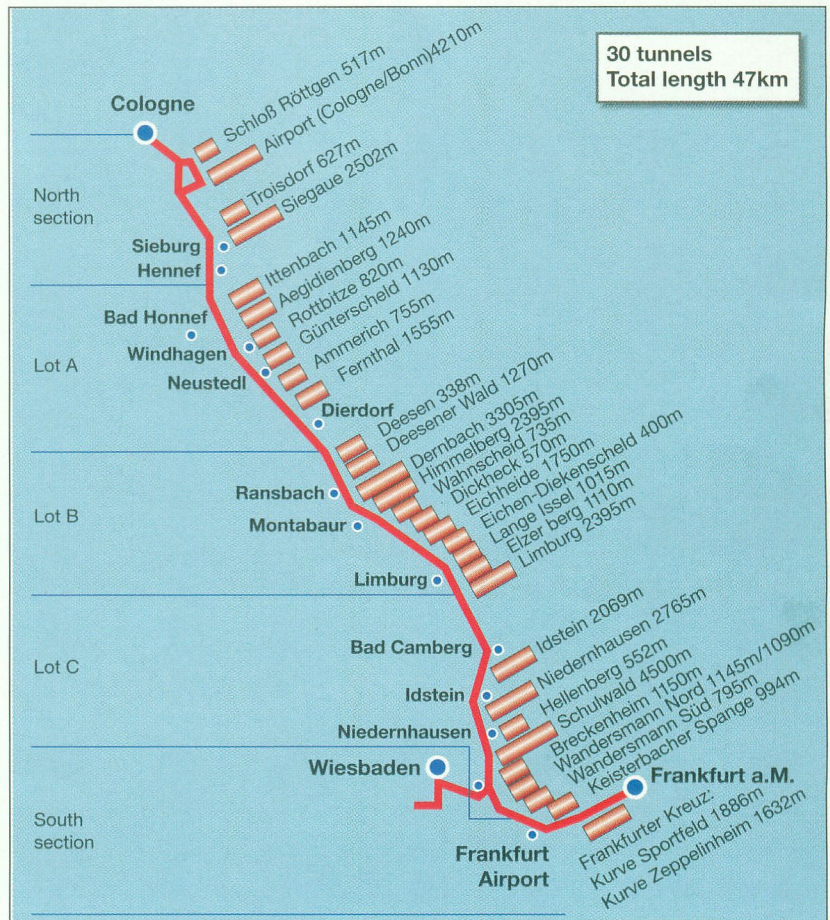
The Tunnel Montabaur JV comprises Holzmann (Germany), Strabag (Austria), AST (Austria), and Wayss & Freytag (Germany). NATM consultant to the design+construct JV is ILF of Austria. Excavation of the tunnels started in May 1998.

The JV is working on four tunnels near Montabaur in the middle Lot B section of the line. The longest of the four is the Himmelberg, at 2395m. This is soon followed by the 745m long Wahnscheid Tunnel and the shorter 575m long Dickheck Tunnel. The fourth is the 1110m long Elzer-Berg Tunnel, of which the central 870m between cut+cover portal sections is mined.

The four Montabaur tunnels pass through highly compacted sedimentary marine deposits ranging from medium strength clays to very hard clay schist, which can require blasting. The tunnels lie below the water table and water ingress through fissures causes rapid deterioration of the backfill roadways and difficulties in manoeuvring equipment through the tunnel.

The JV is working four faces: a steep 3.85% declined heading from the west portal for the Elzer-Berg Tunnel; a face from each portal of the Himmelberg Tunnel; and an advance from the west portal of the Wahnscheid Tunnel, which will follow through to complete the short Dickheck Tunnel (Fig 2).

Of these four points of advance, three are following the two sidewall drift NATM design, with each separate drift excavated in top heading, bench and invert steps (Fig 3). The single heading for the Wahnscheid Tunnel is advancing on the full top heading, bench, and invert sequence, with the bench and inverts excavated in two halves to maintain ramp access to the



30 tunnels
Total length 47km

top heading progressing concurrently about 80-100m ahead of the bench (Fig 4).

On all faces, work is advancing on 1.2m rounds, with fully cement-mortar bonded rebar dowels, wire mesh and shotcrete providing the immediate support. Lattice girders are installed on 1.2m centres in the top headings and Omega profile ribs are used in the temporary walls of the sidewall drifts. After excavation, depending on ground conditions, the crown of each full top heading is supported by between eight and 12 dowels 4-6m long, with 250-350mm of shotcrete reinforced with up to four layers of wire mesh.

Fig 1. Some 47km of the new 219km long high-speed railway between Cologne and Frankfurt (Rhein/Main) includes 30 NATM tunnels, the longest of which is the 4.5km long Schulwald Tunnel

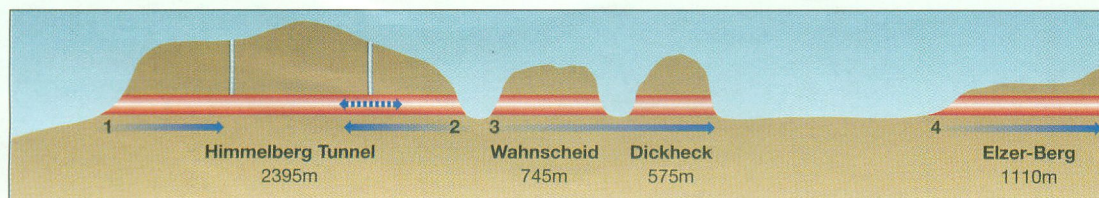


Fig 2. Four complete sets of equipment working 24h/day, 7 days/week are being used to excavate the four tunnels in the Tunnel Montabaur JV contract

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Both dry and wet mix shotcrete are being used on the Montabaur tunnels. "We have our own high output batching plant to produce the wet mix shotcrete as well as concrete for the 350-600mm thick final in-situ concrete lining," explained Kapfinger. "The Elzer-Berg operation, being the most distant from the batching plant, is using only dry mix shotcrete, while the three other headings are using mostly wet mix, with the dry mix available for smaller volume needs, or for working a wet and dry mix section at once."

Contract set-up

The Tunnel Montabaur JV won the \$109.9m design+construct contract for the tunnels in mid-1996 and construction – including the final in-situ concrete lining – was scheduled to be completed in three years (see panel on p36). The JV mobilised the four portals. Each site heading is equipped with a complete set of excavation and support equipment, and three crews of ten men to work on a two 11h shift/day, 7 day/week schedule. Each heading has: a Liebherr 922 tunnel excavator; a Cat 966 loader; a fleet of Volvo dump trucks; an Atlas Copco H145 Boomer for drilling anchor holes and blasting charge holes when required; and an ALIVA AL-500 shotcreting rig.

At the start of the contract the JV established its working plan based on an average advance of 2.4m/heading/day and mainly on a full face top heading, bench and invert sequence. "Unfortunately," said Kapfinger, "and mainly due to adverse geological conditions, we are not maintaining that average. We are achieving an average of about 1.7m/day at present and for three of the headings, we are having to follow the slower sidewall drift excavation sequence."

Even in the Wahnscheid Tunnel the average advance is 1.7m/day due to the mixed face conditions and the need for blasting in some areas. At this rate completion of excavation will be delayed by up to six months. Kapfinger said: "We are considering the possibility of opening two new headings from the base of one of the emergency escape shafts on the 2.3km long Himmelberg Tunnel."

There are two emergency escape shafts on the tunnel, each 8.6m in diameter and about 40m deep. Excavation of both shafts reached tunnel alignment in mid-March. A fourth set of tunnelling equipment, with crews, is likely to be engaged to work alternating headings in each direction.

Turnkey design+construct procurement

In a significant departure from traditional practice, DBProjekt GmbH, the project implementation organisation for the state owner and client, Deutsche Bundesbahn (DB), has adopted a particularly challenging method of project procurement for the central section of the \$4.3bn Cologne-Frankfurt link, with another \$571.4m for the Cologne/Bonn Airport connection.

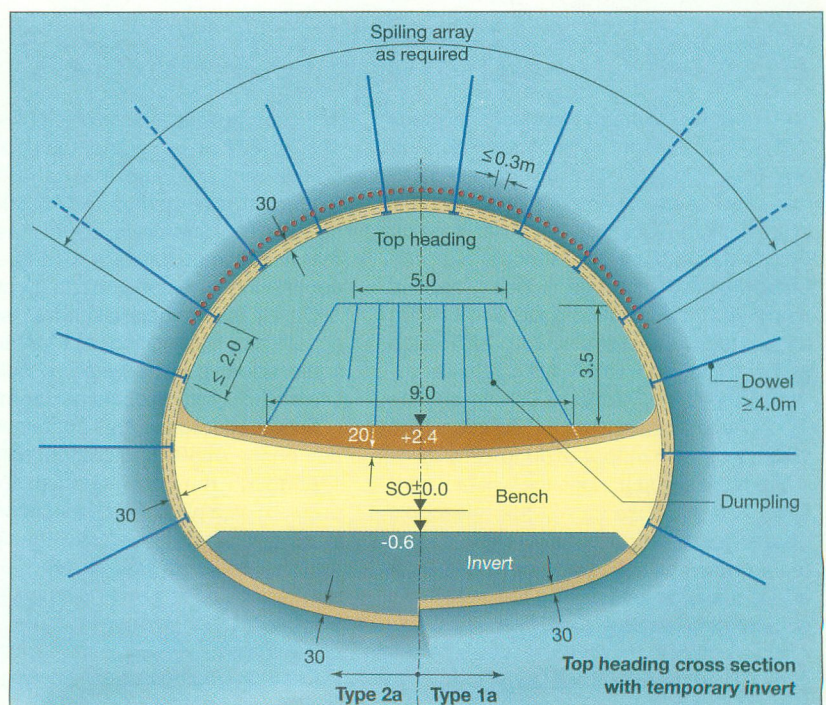
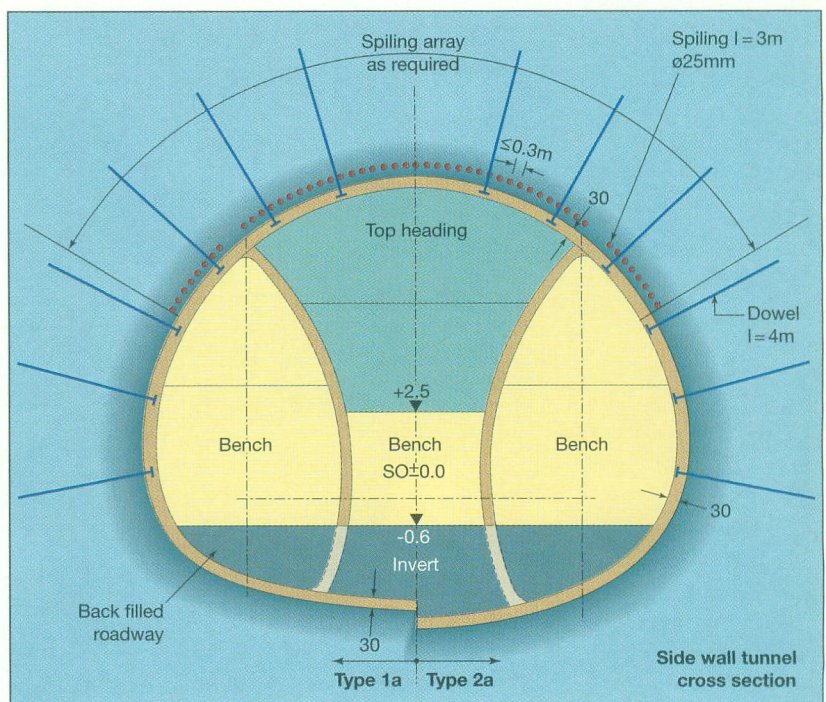
Rather than being directly involved in the day-to-day management and supervision of the new line's implementation – as was the case on the Hannover-Würzburg line in the 1980s – DB devolved this responsibility almost entirely to three large consortia which are responsible for completing the civil works and installing the track and all the M&E equipment in their sections.

"In a significant departure from traditional practice, DBProjekt has adopted a particularly challenging method of project procurement"

Having been awarded huge contracts and with the approved alignment corridor and access to construction sites secured, it is up to the consortia to: define the structures needed to comply with particular performance criteria; design and construct these various structures; and hand over at the end of the overall project due date a complete section of railway ready for turnkey operation of the trains.

Consortia competed for the three large line contracts through 1995 and the contracts were awarded in mid-1996 (Table 1). Once awarded, detailed design for each section contract took 18 months or so. Construction started in late 1997, with the main section

Figs 3 and 4. The sidewall drift sequence (below) and the full top heading, bench and invert NATM method (bottom) are being used, with the assistance of spiling as required, to excavate the Montabaur tunnels, mainly through soft to medium strength clay schist, which can be very hard in places and require blasting



The single-tube, double-track high-speed rail tunnels have an excavated cross section of up to 154m² and will be finished with a 350-600mm thick unreinforced in-situ concrete lining, parts of which will have a waterproofing membrane behind.

Table 1. Award of three turnkey section contracts

Lot A – Arge Mittelstand comprising:
 Max Bögl, Johann Bunte, Falkenhahn Bauges, Alfred Kunz, Josef Möbius, Boll, HR Schmalz, Heinz Schnorpfel, Leonhard Weiss, HF Wiebe, Wittfeld

Lot B – Arge NBS comprising:
 Hochtief, Philipp Holzmann, Bilfinger+Berger, E Heitkamp, Strabag, Wayss+Freytag, Alpine Bau, Ilbau, Beton-und Moneirbau, Hinteregger & Söhne, Thyssen Schachtbau

Lot C – Arge NBS comprising:
 Dyckerhoff & Widmann, Weilit & Woerner, Walter Bau, Ed Züblin

North Section – to Cologne/Bonn airport:
 Various individual contracts let in early 1998 under conventional contracting practice.

South Section – to Frankfurt airport:
 Various individual contracts let in mid-1995 under conventional contracting practice.



consortia engaging sub-contractors to complete the various construction elements. Other sub-contractors will lay the track and install M&E equipment.

On award of the middle section contracts, DBProjekt GMBH set a project-wide completion date of December 2000 after a realisation period of 4.5 years. DB imposed a penalty of \$38.5m against any section missing the due date and causing delay in opening of the full line. Unfortunately, since the start of the project, several extremely difficult and project-wide problems have since become apparent.

Design of the various line structures, including the tunnels, took longer than estimated, as did gaining approval from the owner's design checkers. DB also had problems getting project approval in accordance with EU environmental guidelines. Problems concerning construction site access, and alignment changes instructed after the contracts were awarded caused further delays.

The weather has also slowed railway embankment construction and there have been setbacks due to more difficult ground than expected on tunnels, viaduct and bridge piers foundations. Concerns shared by all three main section consortia over the methods used to estimate the tender prices of the huge turnkey-type design+construct contracts further strained client-contractor relations.

Argument over all these issues brought the contract parties to protracted negotiations in mid-1998. DB agreed to extend the project-wide completion date to May 2002, with the South Section work to Frankfurt Airport (let under more traditional unit price contracts) due to open in May 1999. But there is still a great deal of pressure on the contractors' construction programmes and it is expected that compensation claims for geological problems and other delays will take the project through arbitration and legal battles for several years after the line is completed.

In the meantime, most contractors are incurring extra costs to boost construction resources and mitigate delays as a more cost effective alternative to the \$38.5m late penalty. As an alternative method of major public infrastructure procurement, the Cologne-Frankfurt model is likely to remain a contentious issue for some time.



Shotcrete advances embraced

The Hannover-Würzburg project saw many early developments in shotcrete technology. Now, the very latest in shotcrete hardware and chemical additive technology is in use on the Cologne-Frankfurt project. On the Tunnel Montabaur tunnels, high volume wet mix shotcrete is being applied using ALIVA AL-500 mobile shotcreting units fitted with ALIVA's new AL-277 piston pump. Differing from ALIVA's familiar rotary pump for dry or wet mix shotcrete, the AL-277 piston pump has a theoretical high volume wet mix output of up to 22m³/h.

From the pump hopper, the wet mix concrete is applied via an AL-307 telescopic nozzle boom which is fully rebound protected by metal covers. Compressed air at about 4 bar, together with the necessary accelerator, is introduced to the wet mix concrete about 1m from the nozzle to ensure adequate mix of the accelerator and

sufficient propulsion for efficient spraying. The AL-277 piston pump, the liquid accelerator container and the AL-404 dosing unit are all mounted on the AL-500 mobile carrier. The shotcrete boom has a 16m reach and can rotate 410 degrees with continuous automatic nozzle gyration.

On all the tunnels alkali-free shotcrete accelerator is specified. At Montabaur, the liquid additive is delivered in bulk to the site's 12m³ storage container, from where it is decanted into the 1m³ containers which ride on the AL500 shotcreting machines.

Although they are effective, there is a problem with alkali-free liquid accelerators in cold weather. If too cold, the liquid becomes stiff and causes feed problems through the dosing units, particularly when working at high volume outputs. To overcome the problems, the 1m³ containers on the shotcreting rigs have a heating element

inside to keep the liquid accelerator at +15°C. Certain alkali-free accelerators also limit the thickness of consecutive layers of shotcrete. The Montabaur JV is building the shotcrete lining in 100-150mm thick layers but tests are being carried out on a new accelerator which could allow thicknesses of up to 600mm in one application.

In addition to the advances in chemical and mechanical technology, the quality of shotcreting remains heavily dependent on the skill of the nozzle man. Crews of Austrian, Slovakian and Polish workers engaged on the Montabaur tunnels are producing work of a high standard.

Dry mix shotcrete is applied using the pressurised Rombold silo system. The silos keep the mix in perfectly dry condition until needed and releases it at about 3 bar pressure to achieve a shotcrete production rate of about 4m³/h through the nozzle. Some 90 000m³ of both wet and dry mix shotcrete is needed on the four Montabaur tunnels.

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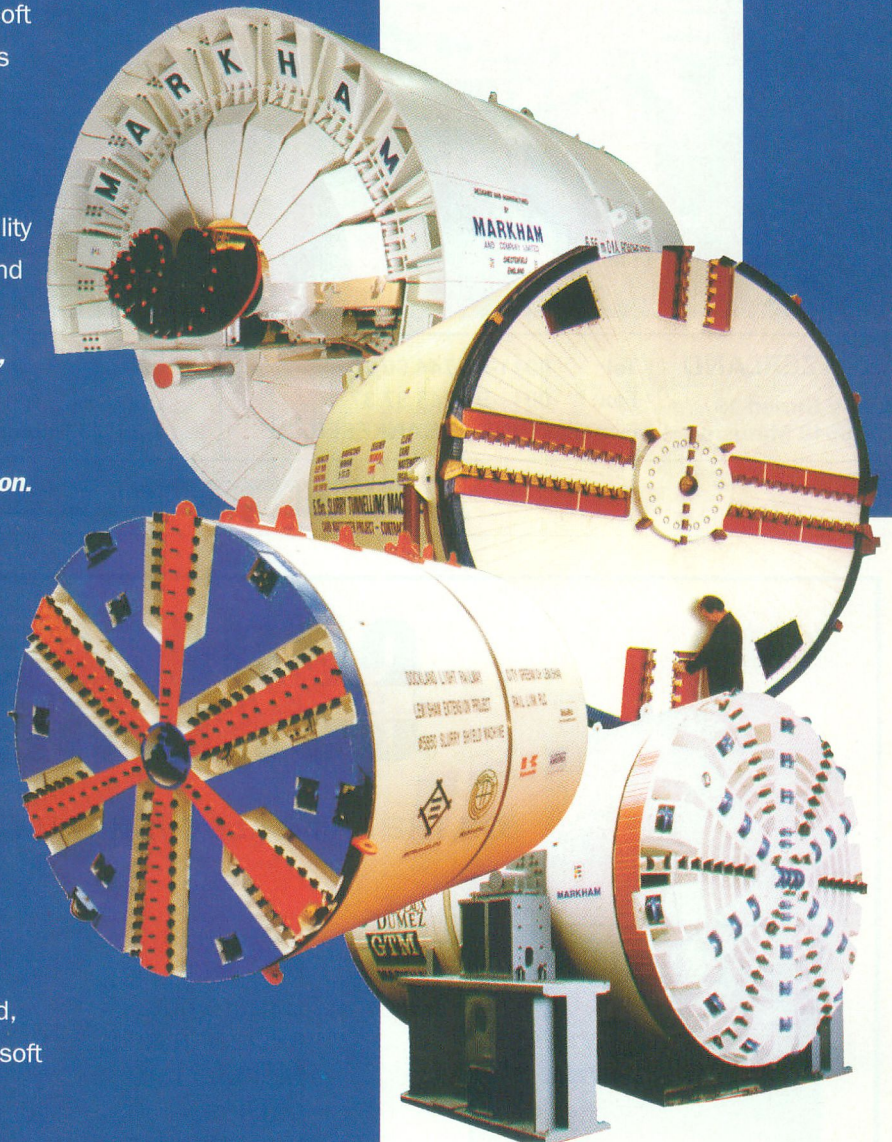
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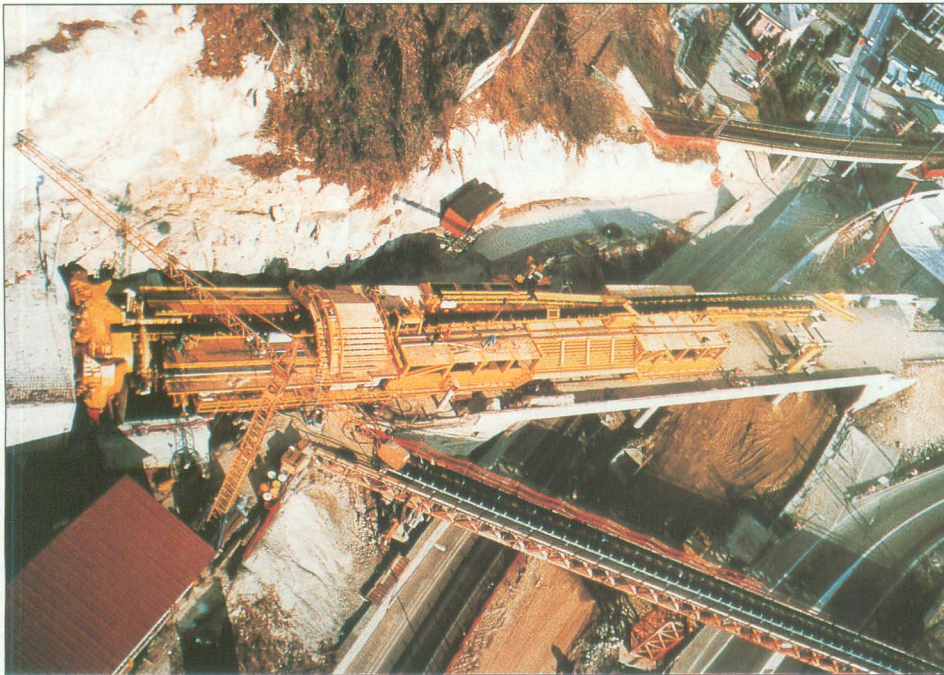
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Pipelaying in built-up areas is always difficult, but with tricky ground conditions, a major transport route and a compressed schedule to contend with, a special approach to management's needed. Technical Journalist Maurice Jones reports on how Thames Water is having a trunk main in south-east London installed under such conditions, all within a target cost.

Fast-track trunk main at Nunhead

Thames Water Utilities is engaged on installing the 1000mm dia., 3km long Nunhead to Deptford water main in South East London. The company has had to bring forward the works for two main reasons. First, it will help supplement the water supply to South East London following an agreement between Thames Water and the UK Environment Agency to reduce abstraction from the chalk aquifer in the Darenth Valley in Kent. Second, it will improve the pressure levels of the existing distribution mains network to give sufficient capacity for the North Greenwich regeneration area developments, including the Millennium Dome. Water for the new main will be fed from west London via Thames Water's tunnelled London Ring Main.

The project also includes the installation of 528m of 600mm dia. main in the Greenwich Park area. This is to lower a high-point in the existing main to improve water pressures in the area.

Initial design

Only three construction methods were feasible to construct the main between Nunhead Reservoir and Deptford Pumping Station in south east London. They were: a long indirect open-cut route; a deep tunnel of 2.5m dia. for the entire route; and a combination of open cut and small diameter tunnel. Both the deep tunnel and the total open cut methods were rejected on cost and because the open cut operation would have been too disruptive.



Joint venture plant in use at the Unclemole drive shaft (21) in Admiral Street

Thames Water engineers chose tunnelling for crossings under substantial surface and sub-surface obstacles such as railways, the A20 (Lewisham Way) trunk highway and major sewers. It was also chosen for deeper sections when cutting through hills for hydraulic efficiency, and where it would be faster, less noisy and create less surface disruption. In all, approximately 1800m of the trunk main has been installed in tunnel, and nearly all the Greenwich Park main by microtunnelling techniques.

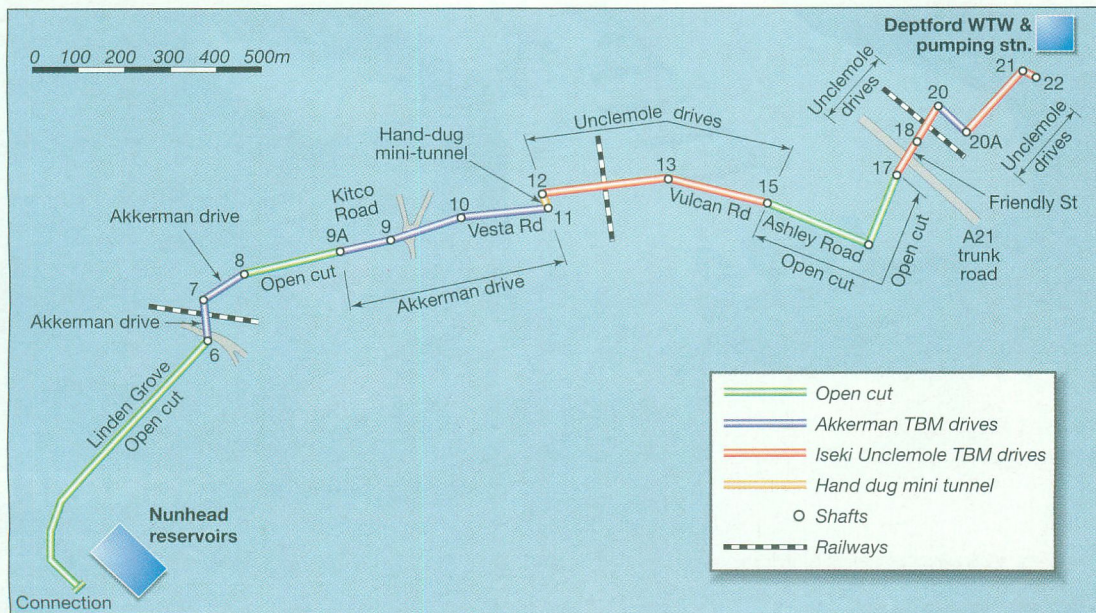
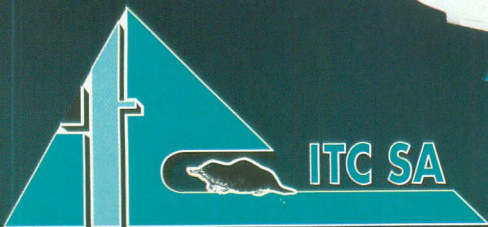
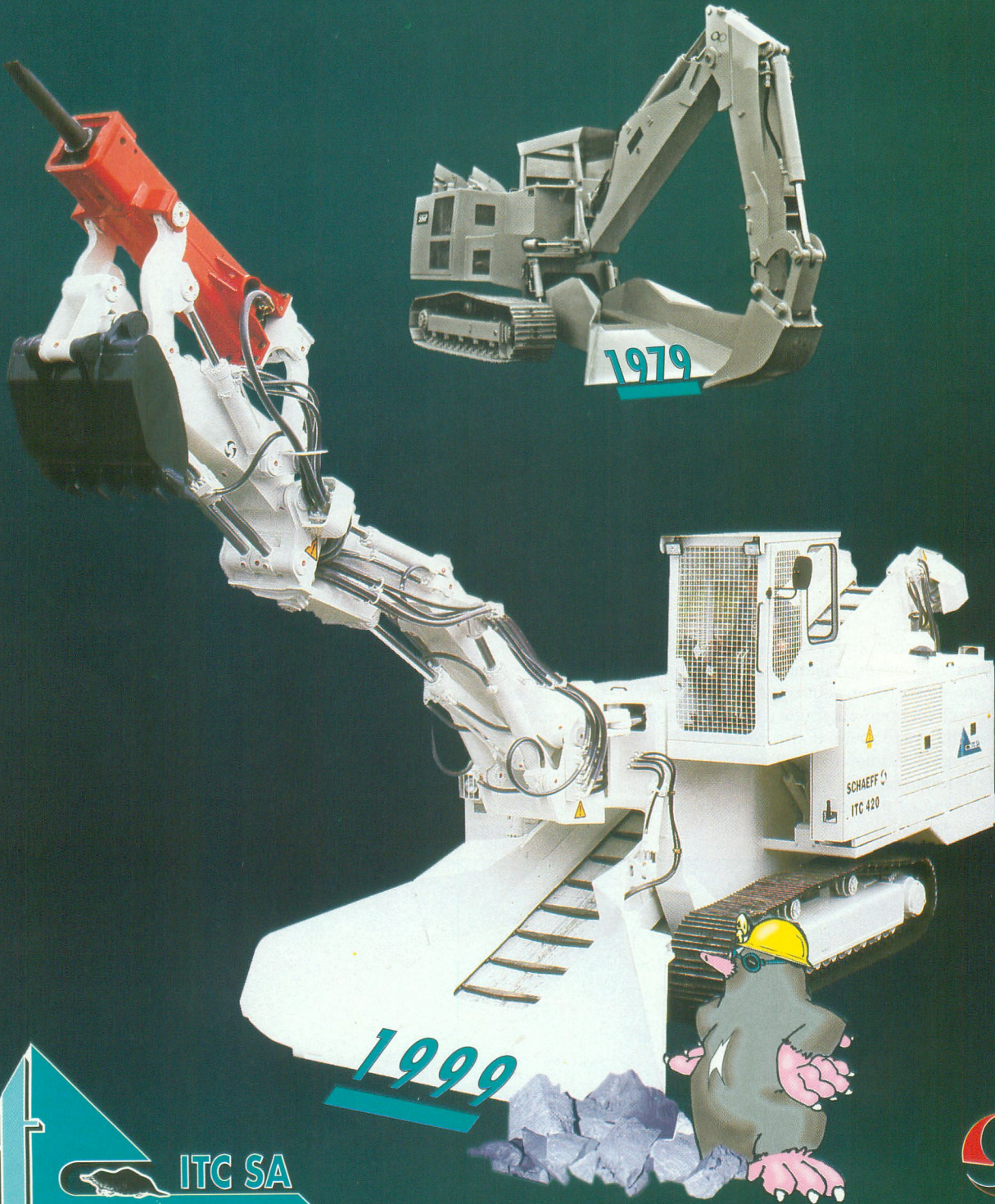


Fig 1. Route of the Nunhead to Deptford Trunk Main showing methods of construction and main crossings

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Tendering

Thames Water engineers began design in November 1997, and tender documents were issued by the end of December. The project was tendered on the basis of their preferred IChemE Green Book Conditions of Contract, which includes a target cost rather than a fixed bid with the risk of claims for additional work.

The contract is being run as an integrated partnering enterprise, with shared 'pain or gain' for diversions from target cost. Because the improved water supply is tied to the fixed deadline developments of North Greenwich, no programme delay can be tolerated.

Thames Water's lead design engineer, John Greenwood, explained that the tenders were based only on the preliminary design. Bidders were free to suggest alternative means of working to achieve the overall objective of the project but each bidder was made aware of the improvements suggested by others.

Barhale Construction and McNicholas Construction, two contractors which have worked frequently for Thames Water in the past, formed a JV for the project and won the contract, against several good bids, on the basis of technical and general resources as well as bid value. Target cost of the works is \$12.9m.

While bidding was in progress, Thames Water Site Services Department carried out site investigations to aid the detailed design which was progressed in parallel. This included geotechnical investigation, land surveying and electromagnetic detection and mapping of sub-surface utilities.

Detailed design

Following the award of contract to the Barhale-McNicholas JV in April last year, the design team, which now included contractor representatives, was split into sub-teams to focus on the detailed design for smaller areas. Working in parallel it was found that the small teams could cover more work than one large team, and a great deal of time was saved.

The project team carried out risk analyses in critical areas, an important part of making the partnering process work. As Mark Evans, the contracting JV project manager, pointed out: "The geotechnics' investigations and risk analysis was invaluable for us to prioritise our work programme. The need for controlled flexibility in meeting our overall objective was recognised from the start, and this enabled us to concentrate our efforts where there might be difficulties."

Shaft construction

The project called for 17 shafts to provide eventual permanent access, plus six extra shafts for construction access. Construction began in May 1998. Most shafts are 3m or 5m dia. and were constructed using ARC pre-cast concrete caisson sinking. Nearly all the caissons had a cutting edge on the lowest ring and were jacked down hydraulically. Exceptions were: Shaft 8, which was underpinned because of a sewer crossing the shaft section; the 3.7m dia., 32m deep

The freshly named 'Aqurush' Iseki 1450mm o.d. Unclemole ready for its first drive



Shaft 12, which was also underpinned; and Shaft 13.

The two longest tunnel drives were to exit from Shaft 13. It was also recognised that the location of the shaft was the most difficult, primarily because of the presence of a high voltage electrical power cable adjacent to the planned shaft section location. Other difficulties at this site were the narrow cul-de-sac nature of the location, the proximity of other utility services and concerns about the stability of adjacent buildings. Obstructions meant that a circular shaft section of the required diameter could not be used.

Several methods of rectangular shaft sinking were considered but all were rejected in favour of a piled caisson. The work was sub-contracted to P Trant, with W J Groundwater responsible for installing and operating ejector wells around the works.

Trant employed a special Giken UP150 'Silent Piler' to insert LX32 18m long Laarsen steel piles around the shaft site. This unit works without vibration and does not require lifting between piles. It 'walks' along the piles, including around corners.

Other features of Shaft 13 construction were substantial jacking walls and headwall for the two Unclemole drives to Shaft 12 (285m long) and Shaft 15 (222m). An exit eye was cored through the old thrust wall for the drive to Shaft 12 by diamond saw to allow the Unclemole to start on the drive to Shaft 15.

Shaft 12 (3.7m dia.) had to accommodate a vertical section of main for a change in level and was the deepest on the job at 32m. Groundwater levels in the Woolwich & Reading Beds necessitated the use of compressed air working to sink the last 10m. Specialist Plant installed and operated an air deck and blister lock. The air pressure could be kept to 0.7 bar, which avoided the need for decompression procedures mandatory for pressures of one bar and above.

The US-built Akkerman WM1430 shield machine

Ground conditions

Plastic London Clay predominates in the western part of the project from the Nunhead Reservoir to Sandbourne Road. From there to Deptford the ground is composed mainly of Woolwich & Reading Beds. These encompass a wide variety of materials including aquifers. Although they are mainly silty clay, the Beds also include shell

bands, sands, some gravel, and hard clay bands and mudstone discovered at shafts 17 and 13. There is also major faulting with mixed zones in some areas.

Using most of the shaft locations developed in the preliminary design, the contractor opted to use tunnelling systems from Barhale's own fleet. These were all pipejacking-based to install Hepworth 1200mm i.d. pre-cast concrete pipes with

steel band joints as sleeves for the main itself. The shield systems comprised a recently purchased Akkerman WM1430 (1430mm o.d./1200mm i.d) open face TBM for the London Clay; a remote control Iseki Unclemole TCC1450 (1450mm o.d./1200mm i.d.); a slurry shield system for the Woolwich & Reading Beds; and an Iseki Unclemole TCC780 (600mm i.d) microtunnelling system for the Greenwich Park work.

Microtunnelling

Between Greenwich Park and Westcombe Park the JV used an Iseki TCC600 Unclemole for another five drives totalling 494m. Ground at the microtunnel horizon comprises dense sand with gravel layers, all bearing groundwater. Adjacent underground services in the area include high pressure gas mains in Greenwich Park itself and a 35in. dia. medium pressure main, both of which had to be traversed without disrupting the supply. Site investigation, including ground probing radar methods, revealed 17th century underground escape passage in this historic area.

Mucking out through the Specialist Plant blister lock used on Shaft 12



was used mainly in western clay and in one sand drive (Shaft 20 to 20A): a total of six drives for 755m. Barhale modified the machine to suit UK needs and Health & Safety Executive requirements. Barhale also ordered a telescopic shield to reduce the minimum drive shaft diameter by 1m. Even so, back and front 'shunts' were required and constructed using heading supports to accommodate the three shield cans.

The shield machine is operated from within the shield and a variety of cutter elements can be changed from there. The westernmost Akkerman drive, from Shaft 6 to Shaft 7, passed under a rail route. Unlike the long Iseki drive (see below), this was monitored only by conventional surveying, since the

line was less busy and the tunnel is in clay.

The JV selected Barhale's Iseki TCC1200 Unclemole system, named 'Aqarush' by local school children, to tackle the mixed ground below the water table. All the work was situated to the east of Shaft 12, having six drives totalling 1050m. With the exception of one drive mainly in sand, JV Tunnelling Agent Andy Alcock reports that the ground on each Iseki drive changed at least once every day and the system coped well with the variable conditions.

The four-stage, three-deck slurry separation system used for this project is the result of a development programme by Barhale and Manvers Engineering to achieve better water recycling. Waste disposal from site has been cut to once every 3-4 weeks instead of every day, an important asset in busy urban areas.

The primary screen removes gravel and balled clay and the secondary unit is a desanding screen. The slurry then passes to hydrocyclones which take out silt particles. The remaining solids are removed by dosing the slurry with flocculant and passing it to a centrifuge. Other operational advantages of the system include less slurry pipe blockages, better face control and reduced downtime for spoil handling.

The longest drive undertaken was 285m long, from Shaft 13 to Shaft 12. This passes under residential buildings, a dual-track railway in a cutting, and a nature reserve. The task gave considerable concern but was completed without a hitch in one calendar month. The tunnel horizon is in Woolwich & Reading Beds just above the Thanet Sands aquifer. The ground could contain unpredictable sand lenses with groundwater at high pressures, while general groundwater pressure at shaft bottom was 7-8m head.

As the drive passed under an important commuter rail route in a deep cutting, the railway infrastructure operator Railtrack had a keen interest in the works. Settlements of more than 10mm were required to be notified to Railtrack, but in fact the largest movement measured was 7mm.

Agreements with the local council limited normal work periods to a single shift between 0800h and 1800h, but concerns over possible ground squeeze on this and other local drives led to weekend working. Three intermediate jacking stations were installed on this longest drive. The main jacking station reached its maximum rating of 600t force as did two of the interjack stations.

At the bottom of Shaft 12, the JV excavated a 2m long stub tunnel to install a 'soft eye' as a reception target for the Iseki shield machine driving from Shaft 13. This comprised a Celcon block (concrete with ash aggregate) wall with a soft concrete circular section constructed using Bulflex pumped grout bags. This design gives more tolerance of alignment inaccuracies than use of a rubber-ring-seal. It also allowed the possible recovery of the shield machine if the drive could not be completed or became badly misaligned.

Normal Unclemole progress rates comprised six 2.5m long pipes a day, although on one drive in homogeneous sand, ten pipes a day were achieved.

The only exception to mechanised tunnelling and open cut was a 32m length of hand-dug pipejack. This links Shaft 12 with Shaft 11 at the end of the Akkerman drives and allowed drive 13 to 12 to be located away from the Vesta Road railway bridge which carries a gas-filled high voltage electrical power cable. The Akkerman drive from Shaft 10 to Shaft 11 was extended to shorten the hand drive.



Project management

The partnering philosophy on this project has been adopted enthusiastically by all parties. Evans emphasised that, from the start, Barhale and McNicholas decided to integrate the project personnel into one 'seamless' JV team. Although the specialities of each partner were employed separately, mainly in the first half of the project (e.g. Barhale on tunnelling and McNicholas on open cut pipe installation), integration progressed in line with the project. Both companies contributed miners to shaft sinking and other resources to the extensive shaft fit out works and commissioning.

The partnering procedure promoted by Thames Water included a number of innovations for smooth

project progress. For example, a 'design liaison engineer' is permanently on site to deal with day-to-day design issues as soon as they arise, as well as the minor diversion of underground services and other points of interaction with concerned organisations and the public. The result was a better compromise on design within the overall specifications and fewer disputes.

With the final tunnelling breakthrough, the heavy civils work was practically complete in February 1999. In May, the trunk main installation is due for completion and, after control and instrumentation installation and commissioning, the main will be operational from the summer, in time for the Millennium celebrations.

Heading for another record break- through!



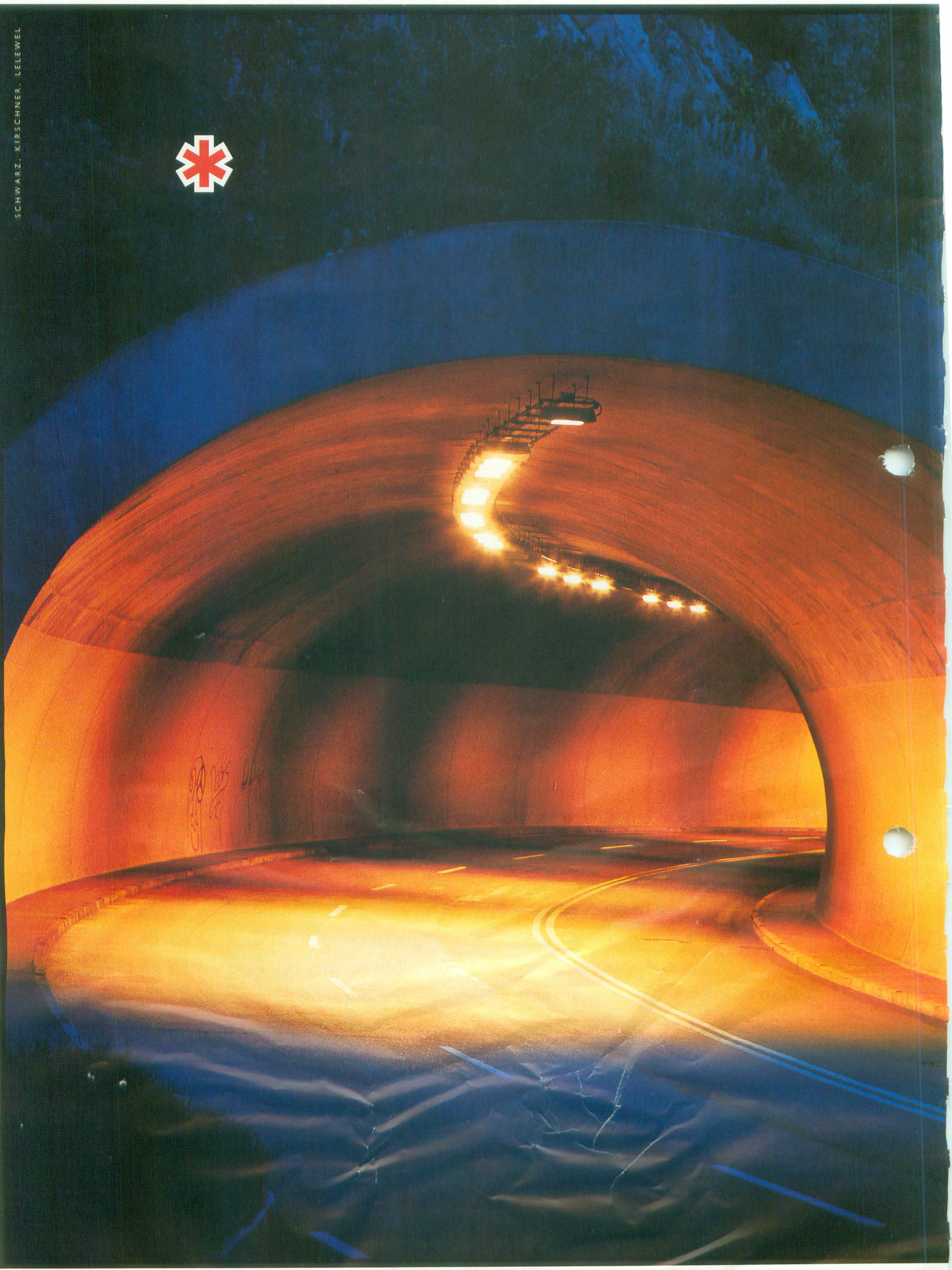
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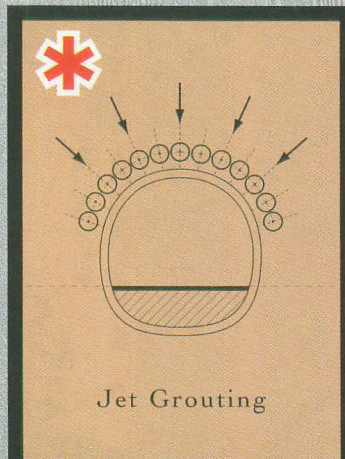
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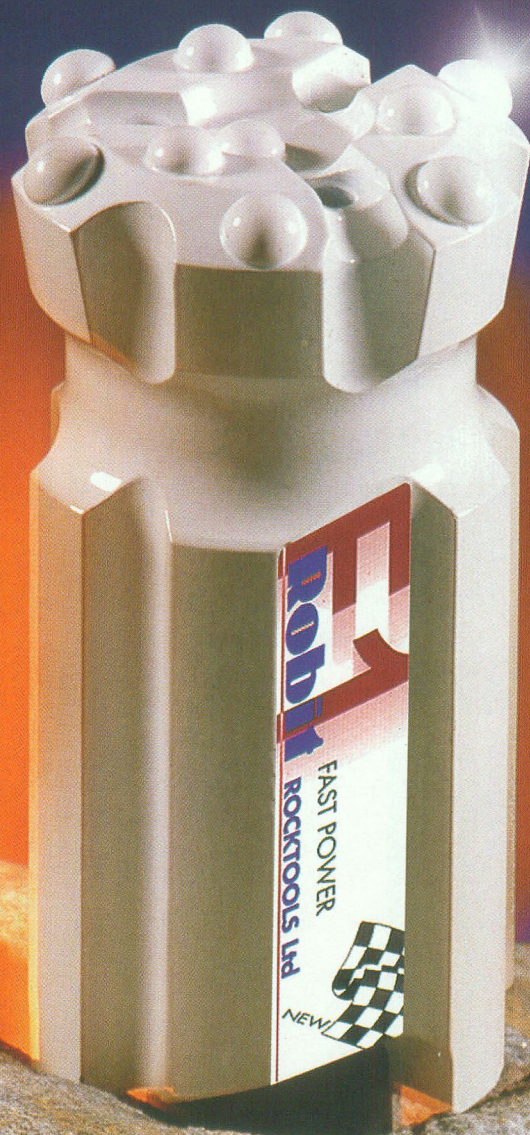
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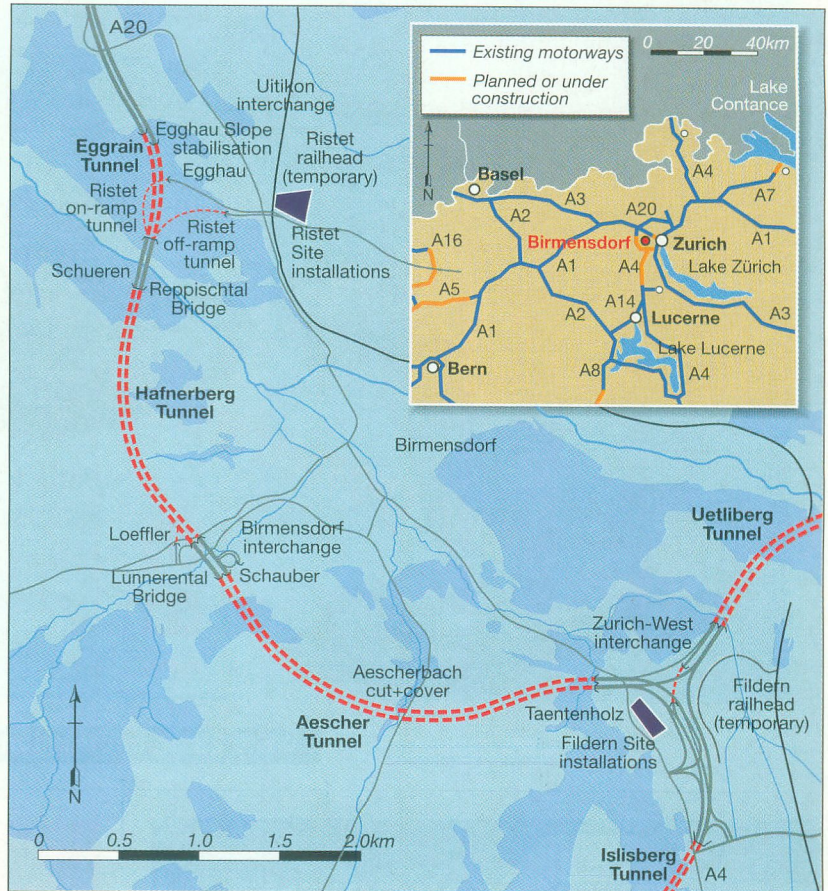
Markus Dettwiler, Electrowatt Engineering's overall Project Leader for the tunnels on the N20 Birmensdorf Bypass, and Otto Schnell, Deputy Head of the National Roads Department, Tiefbauamt of Canton Zurich, describe the project, its design and construction.

The first part of Zurich's N20 northern circular highway – including the 3.3km long twin-tube Gubrist Tunnel – was opened 12 years ago. At the time, the 17km long north-eastern section was essentially a northern bypass of the city, connecting the A1 freeway from Geneva in the west of Switzerland with St Gallen in the east. Missing was the western section of the circular route – the Zurich Western Bypass – comprising of the Birmensdorf Bypass, the Uetliberg Tunnel and a variety of interchanges and other transportation structures.

Zurich has a population of only 350 000 but, as the economic capital of Switzerland, provides employment for commuters from most of north eastern Switzerland. It lies on the main transit routes from south eastern Germany to Italy. The missing link meant that a large proportion of the transit traffic has had to pass directly through Zurich, or use the small local roads in the Birmensdorf area.

Construction started on the Western Bypass in 1996. The 10.6km long continuation of the circular highway extends from the Urdorf area, around the western side of Birmensdorf to the Zurich-West interchange, then runs under the Uetliberg ridge and connects with the existing A3 freeway to Chur (Fig 1). The link is 80% underground and will cost an estimated \$1.9bn. The first part of the link is the 5.4km long Birmensdorf Bypass with three twin tube tunnels, two smaller on/off ramp tunnels and bridge and road works. Construction is expected to take ten years.

The N20 Birmensdorf Bypass section completes



Design & construction of Zurich's bypass tunnels

the western part of the ring road around Zurich and its construction – which will considerably relieve the city of Zurich of transit traffic and the surrounding communities of local commuter traffic is of both national and international significance.

Background

The start of construction on the Western Bypass was celebrated with the ground breaking ceremony for the Birmensdorf Bypass on September 13, 1996. It was an important milestone. The goal of an environmentally friendly, safe and comfortable traffic connection to the west of Zurich was becoming a reality after nearly 25 years of planning, design and legal processes.

It all started in 1971 when the Swiss Federal Parliament decided to augment the national motorway network with the Zurich Western Bypass. After project alternatives developed in the 1970s and '80s for the section in the Birmensdorf region were deemed inadequate, or vigorously criticised by the public, the canton produced a further alternative in 1985. Together

with the Birmensdorf local authority, an alignment west of the town was evolved, running in tunnels through a largely rural environment. This project was approved by the Federal Parliament in 1988. The basic design and the environmental impact assessment were made public in autumn 1991. Under partial consideration of the over 290 objections the cantonal assembly accepted a modified project in 1993. Several parties, ranging from the City of Zurich to environmental and special interest groups, raised legal challenges in the Federal Supreme Court. In April 1996 the court dismissed all the challenges and the Federal Ministry of Transport and Energy approved the basic design in July 1996.

Birmensdorf Bypass

The Birmensdorf Bypass – or N20.1.4 as it is officially known – is a central part of the Western Bypass. The missing motorway section of the N20 joins the existing Bergermoos interchange near Urdorf with the Zurich-West interchange in Wettswil. The section is 5.4km long, of which 4km runs underground in three

Fig 1. Location of Zurich's N20 Birmensdorf Bypass

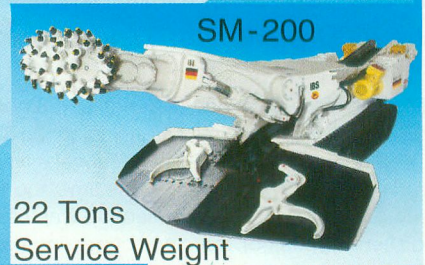
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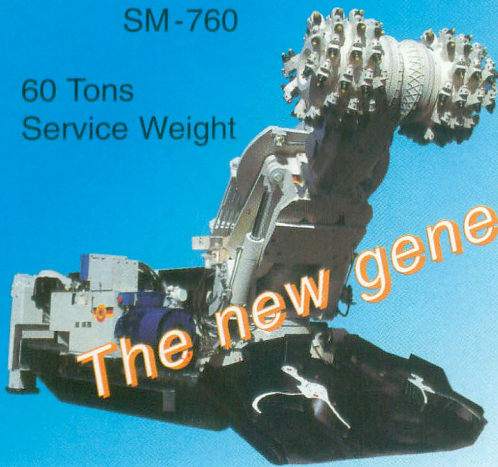


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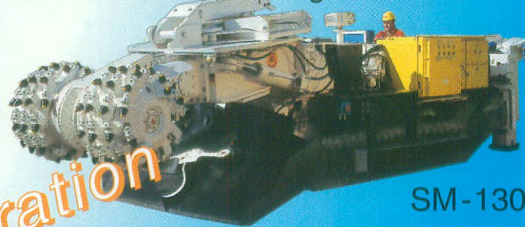
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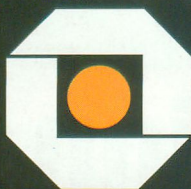
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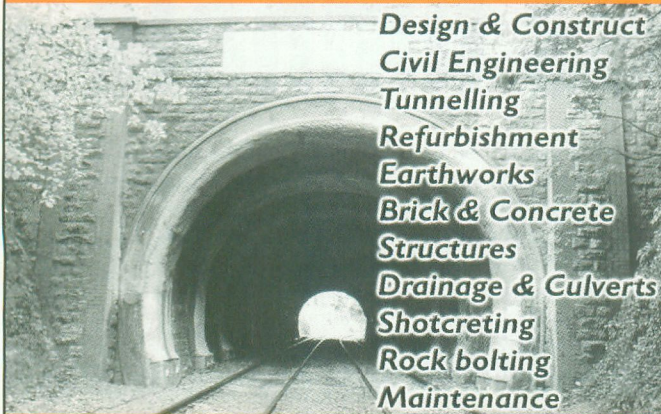


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Table 1. Tunnelling contracts on the Birmensdorf Bypass

Contract	Length	Excavation m ³	Contract Period	Status	Date
Egghau portal	180 m	51 500	1998 - 2000	Construction started	09.1998
Eggrain Tunnel	2 x 480m	120 000	2000 - 2004	Tender planned	06.1999
Ristet on ramp tunnel	350 m	30 000	2004 - 2005	Tender planned	06.1999
Ristet off ramp tunnel	450 m	35 000	1998 - 1999	Construction started	03.1998
Weiherr portal	-	40 000	1997 - 1998	Construction complete	02.1998
Schueren portal	-	20 000	1997 - 1998	Construction complete	02.1998
Hafnerberg Tunnel	2 x 1385m	380 000	1999 - 2004	Tender closed	12.1998
Loeffler portal	-	30 000	2000 - 2001	Tender planned	06.1999
Schauber portal	-	38 000	2000 - 2001	Tender planned	06.1999
Aescher Tunnel	2 x 2160m	600 000	1999 - 2005	Tender closed	06.1998
Taentenholtz portal	-	40 000	1998 -1999	Construction started	03.1999

main twin tube tunnels. The cost of the Birmensdorf Bypass is estimated at \$953.3m.

After joining the existing N20 at the Urdorf-South interchange, the alignment crosses the Bergermoos industrial area on a 400m long open embankment. This is followed by 180m of retaining structures, the Egghau slope stabilisation and, on the upper carriageway, the Egghau cut+cover tunnel. The 480m long Eggrain Tunnel then runs under the Eggrain ridge into the Reppisch Valley, crossed by the twin-deck, 210m long Reppischtal Bridge. The valley is also the location of the Uitikon intersection, whose on-off ramps join the Urdorf road at southern Ristet portal.

The Ristet on-off ramps run in the Ristet on ramp tunnel (350m) and the Ristet off ramp tunnel (450m), merging with the freeway on the Reppisch Bridge. From the Reppisch Valley the motorway runs from Schueren portal, under the Hafnerberg in the 1385m long Hafnerberg Tunnel, day-lighting at the Loeffler portal in the adjacent Lunneren Valley. The Birmensdorf Interchange and the Lunnerental Bridge are situated in the following 260m long open stretch. This is followed by the Schauber portal and the 2160m long Aescher Tunnel, which connects the Lunneren Valley with the Zurich-West Interchange at the eastern Taentenholtz portal.

Tunnel works on the N20. 1.4 Bypass

In addition to tunnels, bridges and short open stretches, the bypass includes a substantial amount of ancillary works. The project was divided by the client into several smaller contracts. This article will concentrate on the tunnelling contracts.

Client is the Tiefbauamt (Civil Engineering Department) of Canton Zurich. Electrowatt Engineering (EWE) has been the client's Engineer for the tunnels on the N20.1.4 since 1988, with responsibility for the following typical Swiss motorway project phases: basic design with public inquiry; revised basic design for approval by the Ministry of Transport & Energy

(EVED); detailed design for approval by the Federal Roads Department (ASTRA); preparation of tender documents for the portal excavations, tunnels and M&E sub-stations; tender evaluation and contract negotiations; site supervision, survey and monitoring; and construction design.

The construction contracts are based on SIA 118, the Swiss general conditions of contract, and SIA 198, the Swiss tunnelling code. The form of contract is essentially non-confrontational and contains substantial risk sharing between client and contractor. It has detailed bill of quantities based on the Swiss NPK system and provides not only for the expected geology but also for worse case conditions. The tunnelling contracts are split into 11 contracts (Table 1).

Design concepts

The main twin tube tunnels – the 480m long Eggrain Tunnel, the 1385m long Hafnerberg Tunnel and the 2160m Aescher Tunnel – each contain two traffic lanes and a hard shoulder, producing a 10.5m-wide carriageway (Fig 3, p51). The excavated cross section varies from around 135m² to nearly 150m². Near the portals at Loeffler and Schauber the Hafnerberg and Aescher tunnels widen at on/off ramps to a 14m carriageway (excavated area of nearly 192m²) followed by a widened section that reaches a maximum carriageway width of 21.5m (an excavated area of almost 337m²) where the ramps split from the main carriageway. The 350m long Ristet on ramp tunnel and the 450m long Ristet off ramp tunnel each contain a single lane and a hard shoulder, giving a 7m carriageway and an excavated cross section of 83m². Similar shorter on/off ramp tunnels merge underground with the Hafnerberg and Aescher main tunnels.

A service canal is located under the main carriageways. Artificial longitudinal ventilation with jet fans was necessary for the Hafnerberg and Aescher tunnels. In three portal areas, Loeffler, Schauber and Taentenholtz, there are electrical substations for main-

Geology

The Birmensdorf Bypass crosses through the Upper Fresh Water Molasse rock and the overlying glacial deposits and surficial deposits (Fig 2).

The Upper Fresh Water Molasse consists of sandstone, siltstone, marls and clayey marls in alternating layers of varying thickness. The bedding is generally sub-horizontal. The marls have a tendency to swell when exposed to air and water.

The composition of the glacial deposits is highly variable. Compact regions of gravelly, blocky over-consolidated glacial moraines or tills with boulders varying in size up to several metres are interspersed with zones of clean gravel beds interlocked with fine somewhat clayey materials. The surficial deposits are of predominantly disturbed loose moraine material together with clay deposits.

Groundwater is present in varying quantities in both the soil and rock, with the water level near the surface. The groundwater circulation in the dense, compact moraine is of minor importance. In the molasse the water tends to circulate in the sandstone layers.

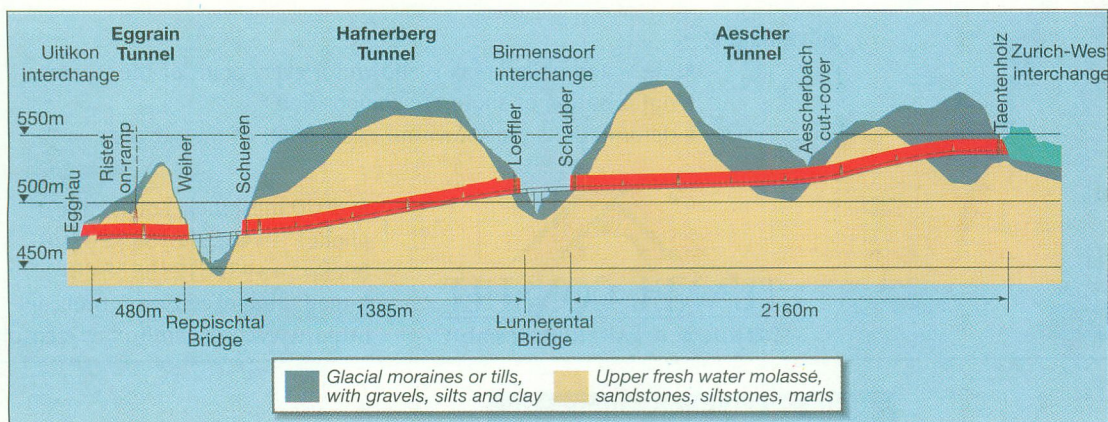
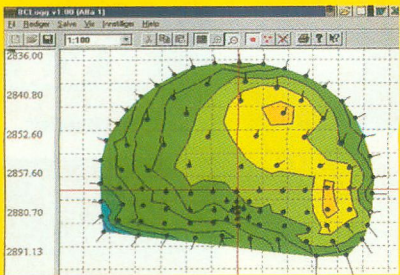
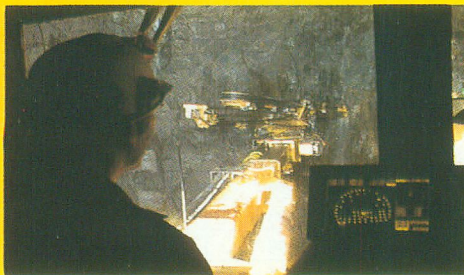


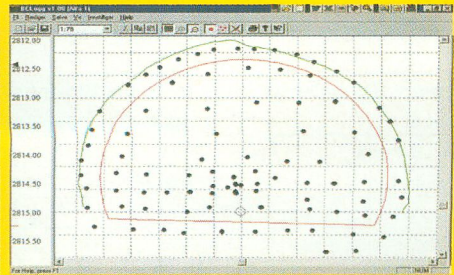
Fig 2. Geological profile of the Birmensdorf Bypass tunnels



Drilling pattern and surface map



Mapping of the blasted tunnel



Blasted profile and drilling pattern

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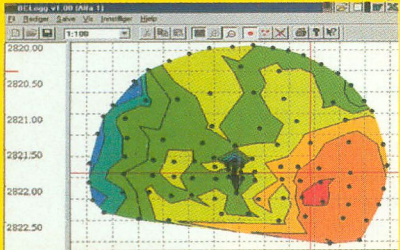
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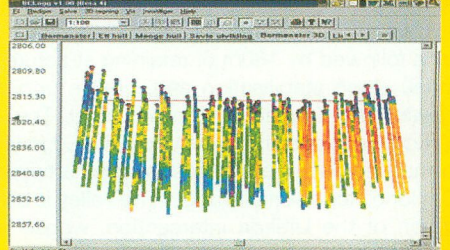
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tenance and traffic safety. There is an electric sub-station integrated with a pedestrian cross connection in the middle of Eggrain Tunnel.

Combined SOS and hydrant niches are placed at a maximum spacing of 150m next to the hard shoulder. Pedestrian cross passages are spaced at a maximum of 300m, with vehicular cross passages in the Hafnerberg and Aescher tunnels.

The tunnels have a permanent reinforced shotcrete rock support that carries the initial rock and soil loads. The bores are waterproofed with a plastic membrane over their full circumference, for environmental reasons and to minimise maintenance costs. The in-situ concrete inner lining consists of a reinforced invert and un-reinforced arch that carry the water pressures and the long-term rock loads from the swelling of the marls and from the general creep and loosening of the rock mass.

Support in soft ground consists of lattice girders, mesh and wet-mix shotcrete with excavation lengths of 1-2 m. In the rock, support again consists of lattice girders, mesh and wet-mix shotcrete with additional temporary anchors as overhead support. Excavation lengths in the rock are planned at 1.5-4m. A variety of measures such as jet grouted or pipe umbrella arches are proposed as additional support in soft ground.

Construction sequence and site installations

Environmental constraints were the most important preconditions of the project approval. There are strict requirements for the disposal of material from the sites and for returning the area to its original condition after construction. All run off and wastewater will be collected on site, partially treated in separate basins and, depending on the degree of pollution, either piped to the Birmensdorf sewage plant or directed into the Reppisch or Vogelsang streams.

Another precondition was that the removal of excavated material and tunnel spoil with heavy duty dumpers would not take place on public roads. The solution was to move the estimated 3m tonnes of spoil by rail. Two temporary railheads at Ristet (on the northern end of the bypass, completed in 1998) and at Fildern (on the western end of the bypass, to be completed in 1999) are planned. The sequencing of the whole construction is based around this spoil removal concept. Apart from some paths and forest roads – which will be temporarily upgraded during construction into a complete network of local haul roads – access is along the motorway alignment from Ristet and Fildern.

The Ristet site installations were completed in 1998, and include a material handling plant for loading spoil on to the railway wagons, areas for the storage of topsoil and tunnel spoil for backfill, offices and workshops for the contractors, as well as offices for engineering staff. Electricity supply during construction is provided by transformers installed in the Reppisch Valley and next to the Urdorf road.

The material handling plant at Ristet for the bypass project was finished in June 1998 together with a temporary bridge for site traffic over the Urdorf road and the railway line between Zurich and Affoltern.

EWE is responsible for co-ordination between the Swiss Federal Railways (the SBB), the operator of the plant and the temporary spoil dump and the various contractors delivering to the plant. Since the end of August 1998, a daily muck train takes around 1000 tonnes of spoil destined as fill for a quarry in the lower regions of Canton Zurich. By the end of construction, around 1.7m tonnes of material will have

Jet grouting for the umbrella arch in the Ristet off ramp tunnel to allow excavation in soft ground

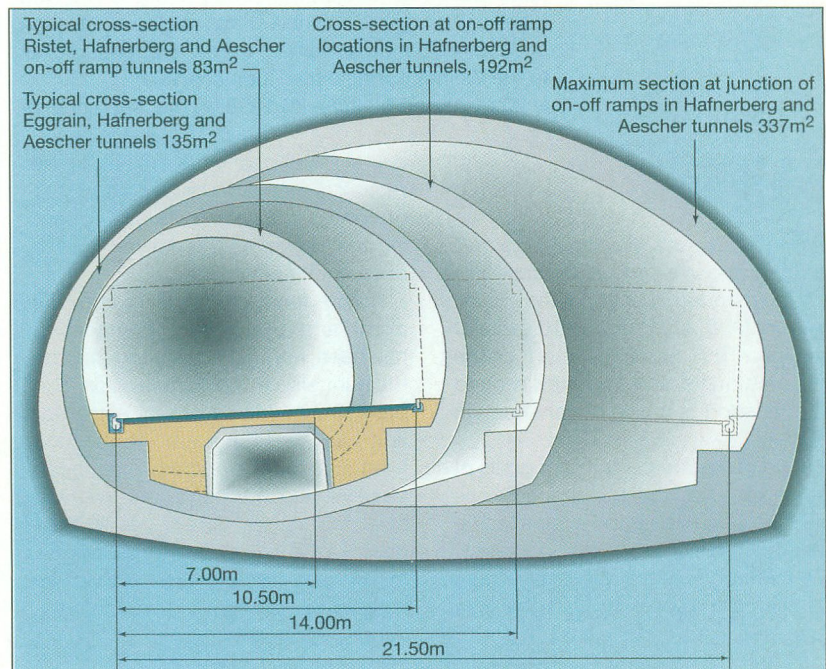


been removed by rail from the Ristet on ramp tunnel, the Egghau cut+cover tunnel, the Hafnerberg Tunnel, the Eggrain Tunnel and the Ristet off ramp tunnel. This represents 110 000 truckload journeys kept off public roads.

To facilitate access to the Hafnerberg Tunnel, several construction contracts were completed in 1998 or are under way. The portals excavations at Weiher and Schueren were necessary for construction of the Reppischtal Bridge, which in turn serves as a haul road during construction of the Hafnerberg Tunnel. The portals were completed in 1998 by a JV between Locher & Cie and GU Tiefbau.

Work on the bridge started in 1998, to be completed on schedule when the Ristet off ramp tunnel breaks through at the end of 1999. The Ristet off ramp tunnel runs from the Reppisch Valley to the Ristet material handling plant and will later connect the motorway to the Urdorf road at the Utikon Interchange. The tunnel was the first to be awarded on the bypass and will be used from the end of 1999 as a haulage and access road for the construction site traffic from the Hafnerberg Tunnel. Only the shell of the tunnel will be built initially. It will only be fitted out after serving for five years as construction access.

Fig 3. Typical cross section of the Birmensdorf Bypass showing the carriageway widths



The Ristet off ramp tunnel is being constructed in two stages – the heading followed by the bench



Current construction status

Construction started in September 1998 on the Egghau slope stabilisation in the Bergermoos area. The contractor is a JV of Walo Bertschinger and Bauer Spezialtiefbau. The design was carried out by an engineering JV of Neoplan and Buro Zinsli, with site supervision by EWE. The alignment runs almost parallel to the contours of the slope. The potentially unstable slope, which is slowly creeping, will be stabilised by a total of 9900m large diameter bored piles up to 40m long. A Bauer BG 40, the largest piling rig in Europe, is boring 1.2 and 1.3m piles at a rate of up to 3/day.

Apart from the piles, 480 prestressed soil anchors with lengths of 30-40m are expected to be used. Part of the project is the portal excavation of the Eggrain tunnel, which is a shotcrete wall supported by 6-8m long soil nails. The underground tunnel in the portal area is shielded by a 30m long line of anchored piles in the underlying rock. The total excavation of some 50 000m³ will be followed by construction of a cut+cover tunnel on the uphill carriageway.

The Eggrain Tunnel will go to tender in 1999, with construction scheduled from 2000 to 2004. The twin tubes will be driven downhill with a staged excavation of heading, bench and invert from the Egghau portal to the Weiher portal in the Reppisch Valley.

Work started on June 26 1998 on the first tunnel of

the N20.1.4 motorway stretch, the Ristet off ramp tunnel. The contract was awarded to a JV of Walo Bertschinger and HASTAG Hans Stutz. Of the 450m long tunnel, 400m will be driven downhill from the Ristet portal. The first 240m are in soft ground, followed by 160m of rock. The tunnel is being excavated in two stages, the heading, followed after about 80m by the bench and invert (left). Some 120m of the heading and around 20m of the bench and invert have been completed.

The excavation is supported by shotcrete, lattice girders and mesh. Tunnelling in soft ground takes place in 11m stages under a jet grouted umbrella arch being installed by Rodio (see photograph on page 51). This consists of 31 near-horizontal 14m long bore holes drilled from the face and from which 600mm diameter piles will be cut and mixed under pressure with a cement-water grout jet. Water pressures in the soft ground are reduced ahead of the face by 5-35m deep well points installed from the surface.

The excavation will last until the end of 1999. After completion of the soft ground stretch, the rock section will be excavated by drill+blast and the lining and temporary pavement installed. The construction cost of the tunnel is around \$10m. Extensive preparatory works for the coming tunnels and the Ristet site installations are included in the contract.

The Hafnerberg Tunnel was tendered in 1998 and tender adjudication is under way. Construction is scheduled from autumn 2000 to 2005. Both tubes will be driven simultaneously from Schueren in the Reppisch Valley towards Loeffler in the Lunneren Valley. Tunnel excavation is performed in stages, the heading followed by bench and invert. An additional heading of 240m will be driven from the Loeffler portal, together with an approximately 110m long heading for the Loeffler off ramp. The Schueren portal excavation will be retained with soil nailed shotcrete support.

The 2160m long Aescher Tunnel, the longest on the project, connects the Lunneren Valley to the Zurich West Interchange. The bore is 50% in rock, 50% in soft ground. The excavation takes place, apart from some minor ancillary works, by means of a heading followed by bench and invert. Near the village of Aesch, the tunnel crosses a narrow valley with no cover. This portion will be constructed in cut+cover and the river bed above the tunnel will be raised some 3.5m.

The Aescher Tunnel is on the critical path for the whole bypass. Its excavation was due to start in spring this year with the main heading at the eastern portal at Taentenholz. The portal is being constructed by a JV of Locher & Cie and GU Tiefbau. The excavation is supported by anchored soldier piles with shotcrete lagging. A short heading will also be driven from the Schaubert portal near the Birmensdorf Interchange. It includes 250m of the main tubes as well as the approximately 140 m Schaubert off-ramp.

The Zurich-West Interchange is situated in the open valley floor in Fildern, west of Wettswil. It lies between three tunnels and connects the Birmensdorf (N20.1.4) with the Uetliberg Tunnel (N4.1.5) and the Isisberg Tunnel (N4.1.6). Both are in their design phases. The Uetliberg Tunnel is scheduled to be constructed in 2001 to 2010 and will complete the circular motorway around the north of Zurich. Construction of the Isisberg Tunnel will start in 2002, providing a much needed direct connection to Zug and Lucerne by 2012. Included in the interchange between the three tunnels are the connections to the local cantonal roads in Wettswil.

Latest progress

Work on Zurich's Western Bypass is progressing well and is on schedule for the planned opening of the motorway in 2008. After around 10 years of design, 1999 sees the start of the major tunnels and the area around Birmensdorf is a hive of construction activity.

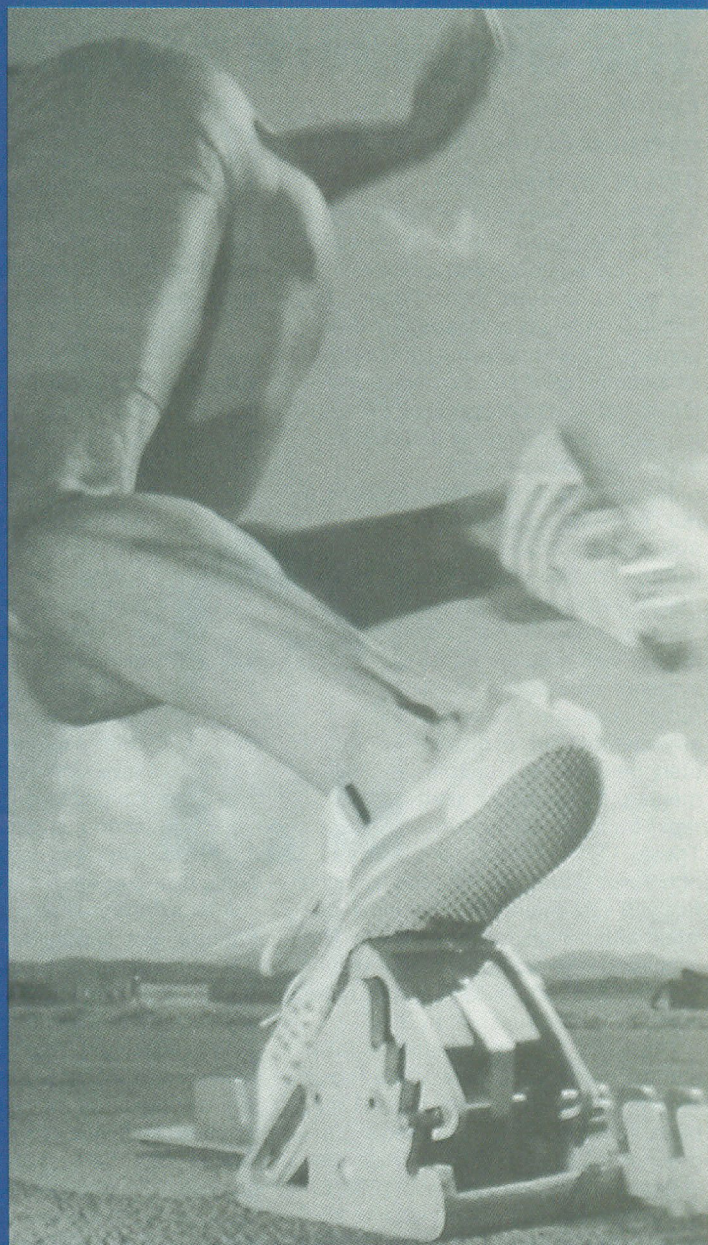
One of the most important goals of all involved in the construction has been to ensure as good a relationship as possible with the local population. Considerable effort has been made to keep the people living in the area informed of progress, and to try to

explain as clearly as possible the technical measures taken to build the motorway and its tunnels, while keeping the impact on the environment to an absolute minimum.

A core team of engineers from the client and Electrowatt Engineering has been working closely together on the tunnels of the Birmensdorf Bypass since 1988. Now that construction has finally started, the reaction from the local populace has been positive and the engineers involved have the satisfaction of seeing their goal – of designing and building a motorway through rural landscape without damaging the environment – becoming a reality.

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The Singapore experience

Low Tien Sio, Deputy Chief Executive, Land Transport Authority, Singapore

The government of Singapore is committed to providing a world class public transport system as set out in its 1996 White Paper. Together with buses and taxis, the development of both heavy and light rail transit systems will form a comprehensive public transport network that will cater for the expected increase and change in commuter travel patterns.

The ambition is to achieve, by 2015, a rail network approaching 400 route kilometres in length. This will comprise a 'backbone' of heavy rail lines radiating from the main city centre, with medium transit systems connecting these radial lines in an orbital arrangement for a distributed network and supplemented by strategic light rapid transit (LRT) systems. These LRT systems are often orbital and will link regional centres and sub-centres to serve the population within each major new town. The aspiration is to achieve a modal split of between 75% and 85% of all trips to be made by public transport by 2015.

The Land Transport Authority (LTA) and its predecessor, the Mass Rapid Transit Corporation, had, since 1983, been implementing a massive programme of metropolitan railway construction. Between 1983 and 1990, 67 route kilometres of railway with 42 stations were completed, of which 15 stations and approximately 22 route kilometres were underground. A major extension of 16km and a further six stations was opened to revenue service in 1996.

In these earlier phases, the ratio of underground to elevated metro was about half. It is significant that, of the projects now under construction, the North East Line, which is 20km long with 16 stations, is all underground.

The trend towards the utilisation of underground space which is evident worldwide is likely to be accelerated in Singapore, where land is in short supply and consequently highly priced. Moreover, intensification of the rail network will inevitably lead to more conflicts

which can only be resolved by underground construction. Elsewhere in Singapore, the Deep Tunnel Sewer Scheme is being implemented, and planning for a comprehensive underground common services tunnel for the New Downtown is well advanced. An underground science park is also being investigated.

All these projects are in the public realm and organisations such as the LTA will play a major role in their successful implementation in the 21st century.


As an informed client it is essential that LTA manages the process well. For underground work, a design+construct



approach has worked well in the past, with few disputes arising. This, to a large extent, can be attributed to the authority's documents being clear and unambiguous in setting out the allocation of risks. Where circumstances differ, alternative approaches have been adopted: on the Changi Line linking with the airport, a different arrangement was considered appropriate due to programme requirements.

After extensive discussions with contractors and suppliers, the authority placed the order for procurement of the TBMs. The contract was subsequently novated when the successful contractor was appointed. Additionally, the provision of fully inclusive and comprehensive insurance cover by the client has resulted in lower premiums and removed this item from the bidding process. The management of risks arising or related to the various projects was actively pursued by the authority rather than left to the contractors.

This responsible approach to competitive bidding, with clear documents and transparent financial dealings, has already resulted in tunnelling being carried out in Singapore at significantly lower costs than those incurred in other cities, despite the perception that underground work carries a higher risk than most other forms of construction.

In summary, tried and tested contract procedures, fairly administered by an informed client, have ensured that tunnelling is economical and efficient. The future for tunnelling in Singapore is therefore assured and the volume of such work is likely to increase significantly in the next century. 

Colin MacKenzie, Regional Director, Tunnelling, AMEC Civil Engineering

As little as a decade ago, virtually all major construction clients in the UK were public sector organisations. Nowadays, thanks to Margaret Thatcher's 20th century industrial revolution, the majority are private companies. The consequences for the UK tunnelling industry have been dramatic. Gone are the days when prospective contractors could expect standard conditions of contract when bidding for underground projects. It is now normal for larger clients to appoint some form of project management organisation rather than the traditional Engineer to deal with their capital works. Such organisations use either their own highly polished conditions of contract or develop a tailor-made set of conditions for each project. There is a surprising range of philosophies to be found in these forms of contract.

At one extreme is the concept of Partnering, in which there is a commitment by the contracting parties to deal with one another in an atmosphere of complete trust, in many cases with transparent accounting arrangements, in shared offices, working in complete unity as a single project team. The team usually includes the client's representatives, the designer, the contractor and some form of cost consultant.

The latter three are selected by the client after a preliminary design has been developed by either his own staff or by a consulting engineer appointed exclusively for that purpose. The project team refines the initial design into a fully detailed design, with each member contributing its respective expertise to make the final design as efficacious as possible. The contractor then carries out the work against an agreed target cost, usually with a gain/pain formula for sharing with the client the results of undershooting or overshooting the target cost. Clients who have committed themselves to genuine partnering have achieved some remarkably good results.

At the other extreme are conditions of contract which require the contractor to bear virtually all the risks inherent in the project, including those arising from design of the permanent works and encountering unforeseen adverse ground conditions. This form of contract is not as unreasonable as it appears. It has the merit of removing almost all the artificiality which plagued the ICE risk sharing conditions of contract under which the client had little assurance of project out-turn cost.

Private clients appear to be prepared to pay a premium for security of out-turn cost, and the bet-

Recent trends in UK tunnel contracting

ions from the industry

ter contractors are becoming much more skilled in assessing risk and in designing means by which some risks can be eliminated and others controlled. The merit of this form of contract is that it forces the contractor to confront reality.

These two extremes tend to be associated with major projects and with clusters of lesser projects. Traditional contractual arrangements still dominate individual smaller projects for clients who do not have large programmes of capital works.

In parallel with these changes in fundamental contractual arrangements, contractors have had to cope with the implementation of significant governmental initiatives regarding safety, quality assurance and environmental issues. However well intentioned have been the motives for these changes, they have generated an enormous increase in the bureaucracy of construction contracts, so much so

that additional staff have had to be deployed to deal with these subjects as individual disciplines.

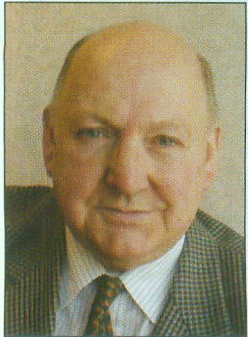
No longer can an agent be expected to cover the whole field. Safety management plans, method statements, quality management plans, environmental impact assessment and control plans now have to be so comprehensively detailed that they are

specialist subjects in their own right. While there is benefit to be derived, it could be argued that some of the traditional clear overall management of the issues is now being reduced because there is a danger that the field staff will get lost in the jungle of detail and miss important fundamental concepts.

There is also, in some cases, a sense of disillusionment because some experienced staff see much of the detail as a means by which blame for a mishap can be avoided, or deflected, rather than as a genuine attempt to get things right. Recent high profile prosecutions arising from construction accidents are certain to enhance that perception, although large compensation awards to injured employees will probably counterbalance that negative attitude by focusing everybody's attention on the real cost of accidents in both human and financial terms.

Tunnelling will grow in sophistication, relying less and less on physical effort and more and more on a workforce trained in multi-disciplinary skills. Tunnelling machines will continue to develop to tackle a wider range of conditions, supplemented by the wizardry of additive chemistry. Tunnel lining development will have to keep pace. Relationships with clients will evolve as evidence of the success or failure of various contractual frameworks accumulates.

It is to be hoped that collaborative rather than adversarial arrangements will prevail, although contractors will have to get used to the idea that it is they who must address risk and either manage it themselves or provide the client with reliable advice on how to do so. **T&I**



Outlook for US consultants

*Jim Monsees, Senior Vice President, Technical Director,
Underground Engineering, Parsons Brinckerhoff Quade & Douglas*

I recently compared the Tunnel Demand Forecast for the next ten years in the US with the same forecast made only seven years ago. Although this is a rough estimate, the results are quite interesting and, if even close to the truth, they may be telling us something. In 1992, the ten year forecast predicted that approximately 378km of tunnels would be designed and built in the following ten years, and this year the forecast is 218 km: a reduction of 42%. In 1992, the then presidential candidate, William J Clinton, stated his would be the infrastructure administration. By that, he surely meant that infrastructure work would increase, not decrease.

The editor of Tunnel Demand Forecast, American Underground Construction Association News, observes that the public thinks that tunnels are becoming more expensive relative to the general cost of living in the US - in spite of the fact that his data indicate a slight decrease in the cost/foot of tunnels over the last ten years.

The main conclusion to be drawn from these two observations is that our industry must find ways to educate the public and to raise their appreciation of what they gain. People generally take our work for granted: residents of San Francisco, for example, expect BART to continue running just as it did after the Loma Prieta Earthquake of 1989. When underground works are functioning, we are invisible to the public. But, as the industry has learned in LA, when we have a problem we are hit with all sorts of negative headlines!

Tunnels under construction now must often be built under tougher conditions than those 100 or even 50 years ago. In those good old days, many tunnels could be planned to cross relatively uninhabited areas and often they could be routed to take advantage of more favourable geology. They affected fewer people, and those they did affect were a little more inclined to accept that the inconvenience was temporary and the improvement permanent. In contrast, most tunnels today have to be built where the people are because that's where the need is. As a result, unfavourable geologies must be dealt with

rather than avoided and ways to minimise disruption must be everyone's concern.

So, what conclusion can be drawn? It is my belief that ever increasing populations will continue to demand ever more infrastructure services and, in large part, those services will have to be built underground. So, our industry can look forward to exciting challenges and we must rise to them.

In November 1998, J L Lammie conducted a survey of the US construction industry through the eyes of the members of the Moles. Here are a few of the conclusions:

■ Requirements for qualified people will continue to increase for consultants and contractors. As a result, we face a possible people shortage to meet future demands for underground work.

■ We must continue the efforts started in 1954 to improve contracting practices. Design+build

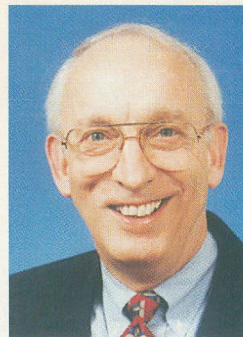
and other non-standard forms of contract will become more popular and, other forms of disputes resolution will also find favour. The latter will include disputes review boards, arbitration and mediation - all in lieu of litigation. Interestingly, contractors like to use mediation, but do not like arbitration.

■ Competition will increase and owners will pay more attention to issues such as:

- Cost containment
- Rejection of unqualified bidders
- Greater use of partnering
- Increased use of alternative contracting methods to save on cost and/or schedule

■ The fact that both designers and contractors perceive owners as less ethical than in the past.

In summary, our outlook should be optimistic, but we certainly should not let up on our efforts to introduce new contracting approaches and new technology to control costs and reduce disputes. Our emphasis on providing quality people and quality work must be redoubled. Most importantly, we must take every opportunity to inform the ultimate owner - the public - of our successes. Every time they turn on the tap or get on a subway, they should remember that these services were brought to them by means of underground construction. **T&I**



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Thirty years of pipejacked tunnelling

Thirty years ago, pipejacking was a very basic technique. Miners worked inside a simple steel shield excavating by hand to install modified open cut pipes by jacking with short stroke hydraulic jacks and spacers. The pipelines were used primarily for short crossings under existing structures, roads and railways in stable soil conditions. The techniques used for excavating and controlling the face, steering the shield and controlling the jacking forces were crude, with the result that pipes were frequently damaged and line and level of the finished pipes were often out of acceptable tolerance.

Over the last 20 years, outstanding advances have been made to transform this basic technique into a sophisticated method for accurately installing high-quality pipes in a wide variety of ground conditions. Now pipejacking is used for the installation of major sewerage infrastructure works, often including drive lengths of several hundred metres and at cut diameters of 200-3000mm.


The most significant development was the introduction in the early 1980s of mechanised microtunnelling systems from Japan and Germany. The initial development of microtunnelling machines was driven principally by the Japanese to provide a safe, reliable, cost effective means of installing extensive first time sewerage collection systems into Japan's crowded cities. It was introduced as an alternative to open trench installations and received the support of the government authorities as it provided numerous

advantages, including:

- Fewer road closures.
- Reduced traffic disruption.
- Negligible road reinstatement.
- Fewer hazards for pedestrians
- Improved safety for the installer and road users
- Minimum spoil removal
- Stronger pipes with long-term maintenance advantages
- Reduced risk of damage to existing services or nearby structures
- Minimal physical, social and environmental disturbance

Microtunnelling machines are essentially miniaturised versions of full face TBMs. Their development generated the requirement for the remote control of all functions, including operation of the shield machine, jacking system, line and level control, soil removal and pipe lubrication.

As with all tunnelling processes, the geology determine the most suitable excavation and face support methods. A range of machines with various excavation and ground support characteristics is now available to provide economic installations across all ground conditions, from soft, unstable soils to solid rock.

The application of mechanisation to the pipejacking process alongside developments in pipes and shaft systems have all combined to establish an efficient and economic solution for the accurate installation of pipejacked tunnels. 



*Les Allen,
Managing
Director, Euro-
Iseki*

Challenges for the tunnelling market

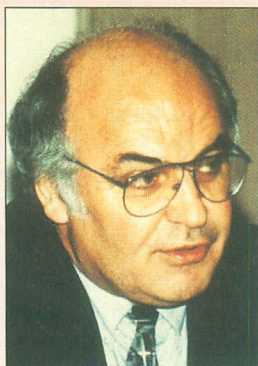
Mechanical tunnelling technology and No-Dig pipe installation are market segments of the future. To meet these challenges we must minimise the risks of the business and make the best use of its possibilities.

I am convinced that mechanical tunnelling will continue as a growing market into the next millennium. Current examples include transport tunnels in the Netherlands; the fourth tube of the Elbe

Tunnel in Hamburg; the current large-scale Zurich Thalwil project; the airport link tunnel in Sydney; and the metro tunnels in Madrid, Singapore and Bangkok. Examples in the No-Dig sector include the extremely extensive sewage system projects in Bangkok and the considerable growth of microtunnelling activities in eastern Europe.

Projects in South America, like the drinking water tunnel in Buenos Aires, are examples of the future of build-operate-transfer (BOT) schemes. These privately financed projects can be carried out with resort to meagre public funds.

During the last few years, the demand for No-Dig systems has increased tremendously



Martin Herrenknecht

in line with the desire for tunnelling to be performed as efficiently, safely and free from pollution as possible. Important projects are only possible with the use of this technology.

However, the tunnelling industry has to face the fact that it is linked to conditions in the construction industry and the economic situation as a whole. Projects are therefore often postponed. Contractors on actual projects are faced with increasingly higher

demands in terms of profitability, meeting deadlines and safety. We as machine manufacturers can help ensure that they, our main customers, are able to meet the high demands placed on them. This will remain an important function of our industry.


To optimise our business activities we must operate on the world stage and try to level out the economic fluctuations. This requires a strong presence in the main markets through local branches, good representation and, if necessary, cooperation.

Herrenknecht offers all methods for machine operated tunnelling and No-Dig pipe installation to deal with high degrees of ge-

otechnical difficulty and the company supports contractors to meet strict deadlines. This has been achieved through continuing development in such areas as: change of operational mode with one machine; soil conditioning; tool applications; control & monitoring; possibilities for long-distance tunnelling.

I foresee that machine operated tunnelling and pipeline construction will gain growing acceptance in the future as a result of the enormous technical developments that have taken place to increase the safety and efficiency of our technology.

Apart from complex machines that are necessary for extremely demanding projects and require well trained operators (for example, the fourth tube of the Elbe Tunnel), simpler, extremely robust machines will still be necessary to perform tunnelling and No-Dig projects quickly, efficiently, requiring low maintenance. This is also a challenge.

Private financing of tunnelling projects will result in an additional boost for the expansion of mechanical tunnelling because, in terms of the final price, the quality and the time required, this method will be accorded preference over the sprayed concrete method. There are enough perfect examples in Switzerland to bring this point home. 

TBM trends in the next ten years

The use of TBMs in soft ground is now accepted world-wide, while in hard rock, even in mountainous areas, TBMs are overtaking conventional techniques to become the major construction method used.

Various fundamental principles in the design of TBMs are now established. Examples of these are: stabilising cut faces in soft, unstable ground; the theory of cutting rock with disc cutters; and basic formulae for establishing TBM specifications. Other essential techniques are also highly developed, such as: face pressure control; hydraulic muck transportation; earth pressure control; and the use of picks and screw conveyors.

At present, the type of TBM to be used is selected primarily according to the geological conditions anticipated. This may be a slurry machine; an EPB machine; a convertible TBM; a hard rock open type TBM; or a hard rock shielded type; etc. Furthermore, mechanical considerations of TBM design limitations have required that construction plans be adjusted to suit TBM capabilities.

Developments must now be directed towards TBMs which are more flexible in their use and which can adapt more readily to the prevailing ground conditions or con-

*T Matsuda,
Chief
Representative
for Kawasaki
Heavy
Industries
(UK) Ltd in
Europe*



tract alignments. Examples include: machines which can excavate around sharp curves (to follow street alignments); carry out non-circular excavations (for stations or storage caverns); or bore for long distances without intermediate shaft access.

The importance of tunnels, both socially and environmentally, is increasing as over-ground space becomes more valuable and protected. The demand for larger and deeper tunnels will increase. There is, however, a practical limit to the manufacturing and use of much larger TBMs, so new construction methods based on new concepts will need to be developed. As far as tunnelling at depth is concerned, technology for removing and discharging muck

from depths of over 100m will be required.

In the field of hard rock, further developments to enable machines to traverse different kinds of rock can be expected. It will be necessary to build machines which are easily adaptable from closed face pressurised excavation to open excavation in stable ground without support.

In the next ten years, therefore, the major TBMs to be used will be those based on, but extended from, current technology. However, evolution into a new generation of concepts can also be expected. These will result from merging not only the structure but also the basic underlying principles of hard rock and soft ground TBMs that will enable excavation to continue uninterrupted, regardless of the prevailing geology. The savings which these machines will ultimately generate will justify their development costs, and total construction costs will remain competitive.

As far as TBM suppliers are concerned, geographical boundaries will continue to disappear as partnership and co-operation flourish worldwide. This can only be good for the global development of machines. 'Cohabitation', as the French put it, is becoming increasingly important, as it is in so many other areas of business. 

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- 6.1m Howden Backhoe Shield with Segment Erector
- 3.84m Lovat EPB Shield with Screw and Conveyor, Type ME151-SE, with Erector
- 3.35m Decon Hand Dig Shield
- Dosco Roadheader Mk 2A
- Dosco TM 1800 Roadheader - Sledge Mounted

Excavators

- Atlas 1104 Excavator (Tracked) 360 degree
- 2 No Atlas 1602 Excavator Tunnel (Tracked) 360 degree
- Webster - FEC Excavator Arm 345 degree Rotation
- 2 No MBT Robojet Spray Arm on Atlas 1302 Excavator Wheeled Chassis
- Kobelco SK032 Mini Excavator 3.5 Tonne
- Kobelco SK060 Excavator 7.0 Tonne
- 2 No Case 888 CK 360 Excavator Rotary Boom

Ingersoll Rand Electric Compressors, 6 to 20m³/min plus air receivers

- SBS Type TS Shotcrete Equipment
- Schwing BPT 1000 Concrete Pumps
- 25t Gantry Cranes, Alimak Passenger Shaft Hoists
- Rolling Stock - Side tip and bottom discharge muck skips, flat cars, manriders, concrete cars and segment bogies
- 100kW Diesel Generators
- Korfmann, Woods and Engart fans, 15kW to 65kW, plus ducting
- Various muck skips, bottom opening/scow end, 5m³ to 25m³
- Slurries Treatment Station - Fives - Cail Babcock
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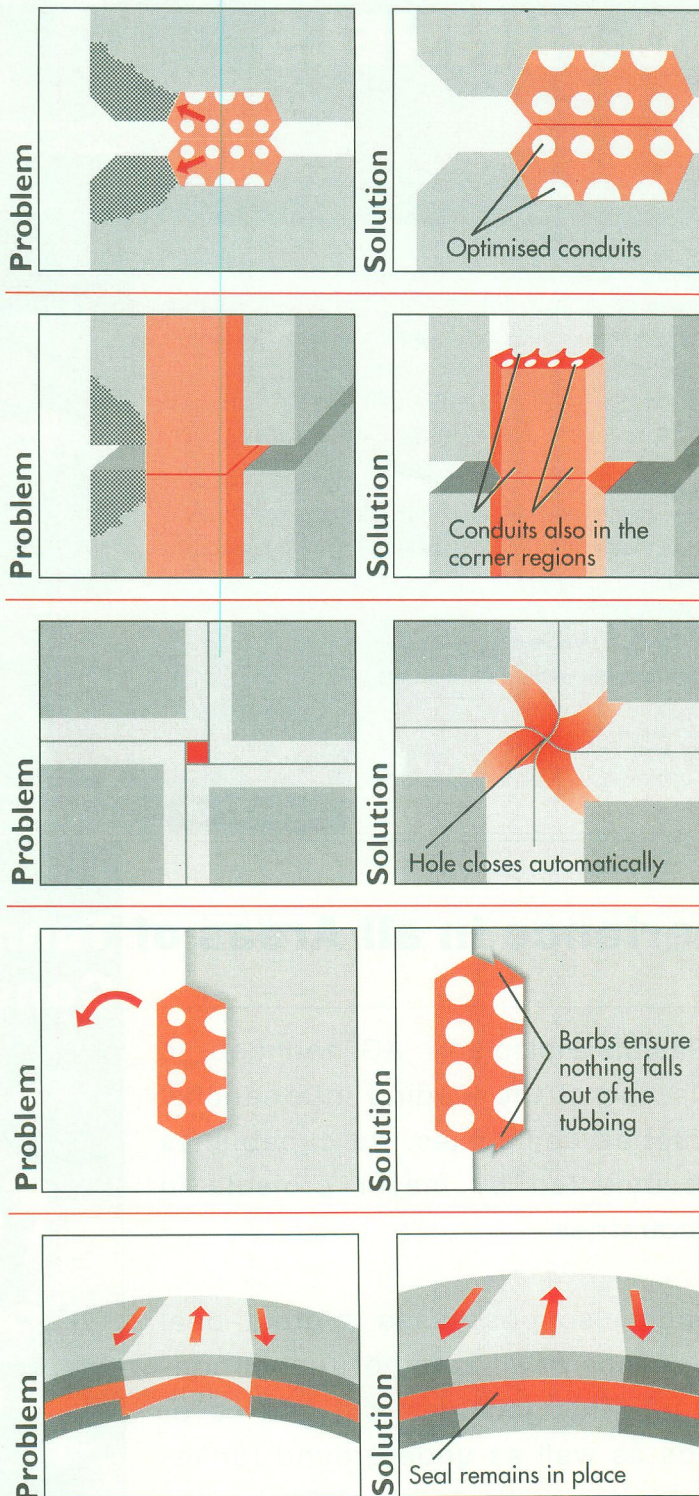
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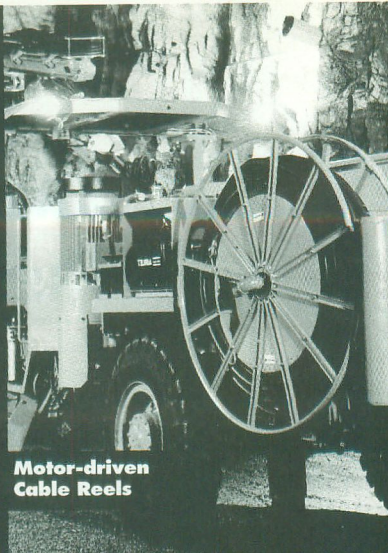
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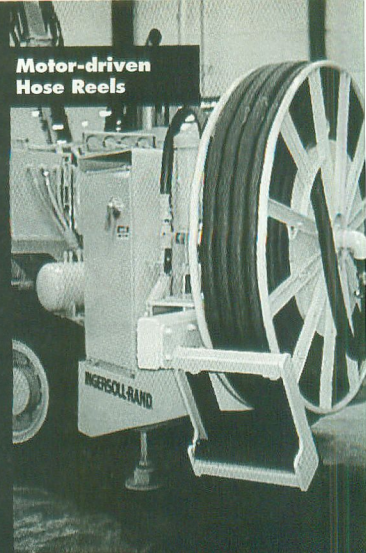


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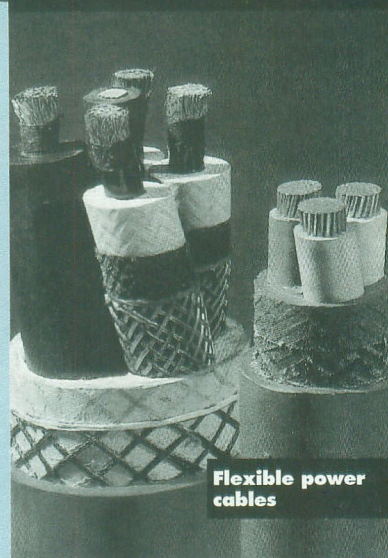
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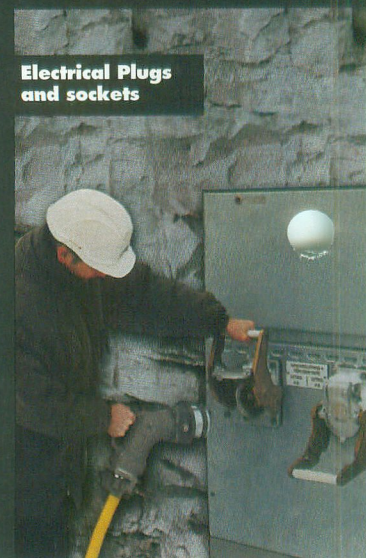
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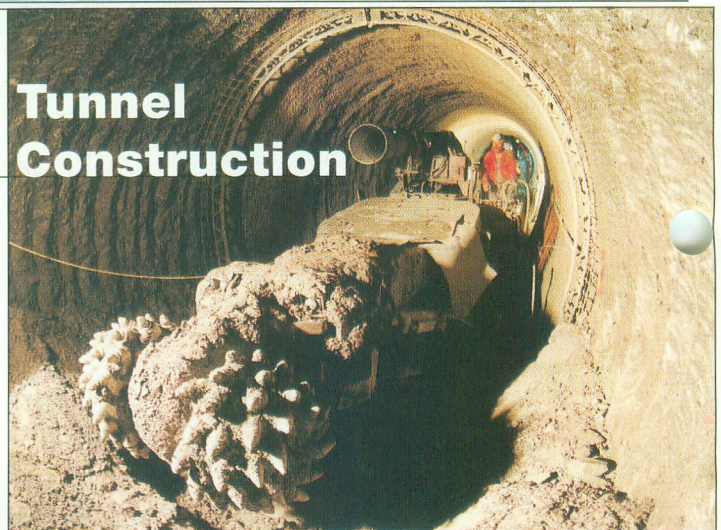
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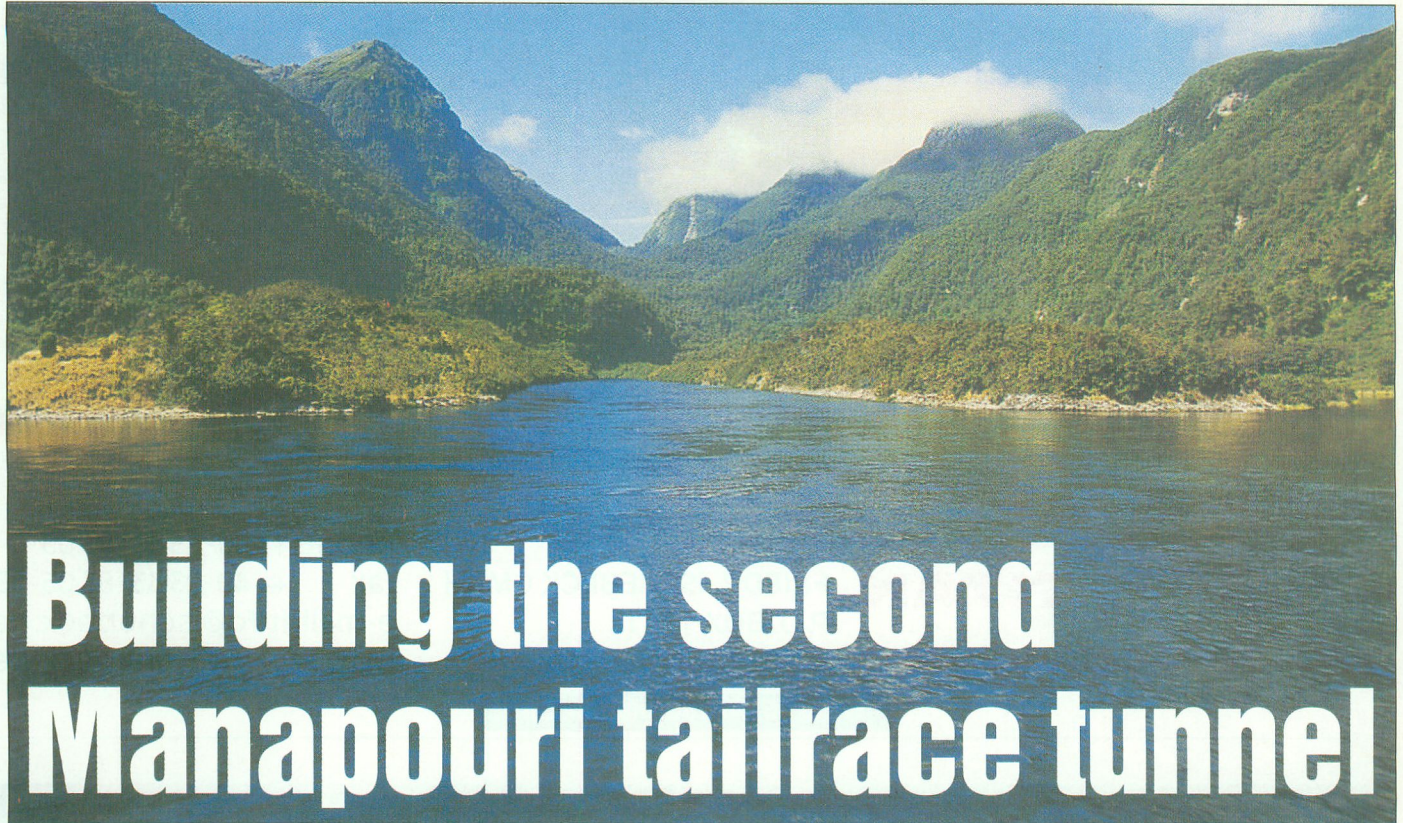
Holzmann also possesses a great deal of experience in all areas of tunnel construction. This includes cut-and-cover methods as well as underground tunnelling methods, particularly shield driving.



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Deep in the heart of New Zealand's South Island, in a world heritage national park in one of the most beautiful and remote areas of the world, lies the Manapouri Power Station, a 700MW hydro facility operating since 1969. To maximise output, a second tailrace tunnel has become necessary. Marc Papke, FDI Project Engineer, and Brian Heer, Assistant Project Director, Electricity Corporation of New Zealand (ECNZ), review the history and progress to date.



Building the second Manapouri tailrace tunnel

Truly hydro country, the coastal portion of the Fiordland National Park is blessed with around 7.6m of precipitation annually, whereas the 'dry' side receives only 3.8m. The project site is only accessible by water or air. Power is generated by diverting water from Lake Manapouri to the underground power station through vertical penstocks to seven 100MW nominal capacity turbine generators located approximately 178m below lake level. The 10km long, 9.4m equivalent diameter concrete lined tailrace tunnel then discharges into Doubtful Sound which flows westward into the Tasman Sea.

Shortly after the station was commissioned in 1969, it was realised that the hydraulic head loss in the tailrace system was higher than predicted by the design calculations. This, compounded by the fact that for environmental reasons Lake Manapouri was not raised to the original intended level, meant the maximum output of the station was around 585MW.

Feasibility studies were conducted in 1992-1993 and it was concluded that the construction of a duplicate tailrace tunnel using a TBM was a viable option for increasing output. The second tunnel will boost the station's peak generation capacity to 760MW and enable ECNZ to produce an additional 640GWh/annum in a mean year. This is enough power to meet the needs of 64 000 households.

In February 1997, a US\$131.6m contract was awarded to a JV of Fletcher Construction (New Zealand); Dillingham Construction International (US); and Ilbau (Austria) for construction of the second tailrace tunnel and its associated facilities.

Project description

Tunnel Two is 9.6km long and is being driven by an Atlas Copco Robbins 10.1m diameter, open face, main beam TBM. The second tunnel runs parallel to the existing tailrace tunnel (Tunnel 1) at a distance of around 70m. The profile of the bored section of tunnel is: 12.5% (decline) for approximately 270m; +0.1% for 8690m; and +3.0% for 642m. It is anticipated that Tunnel 2 will be unlined for approximately 56% of its length, whereas the drilled and blasted Tunnel 1 was

Fig 1. Location of second Manapouri tailrace tunnel

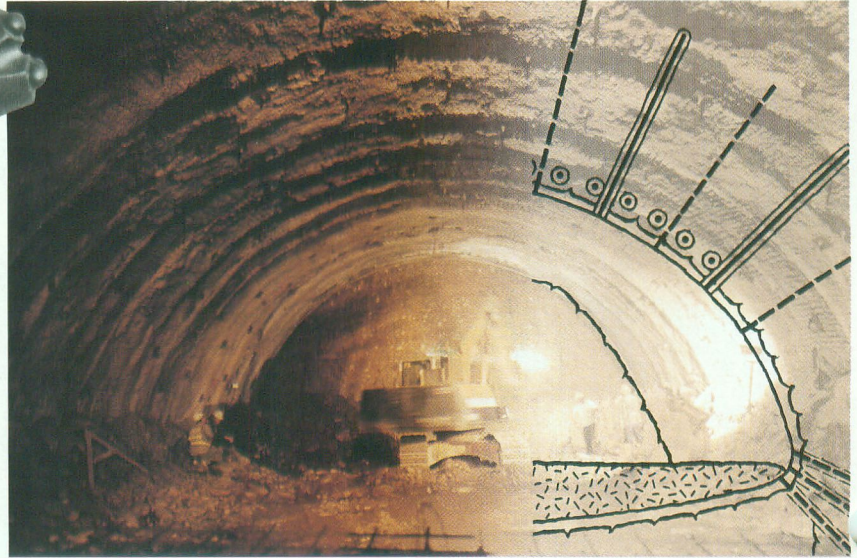


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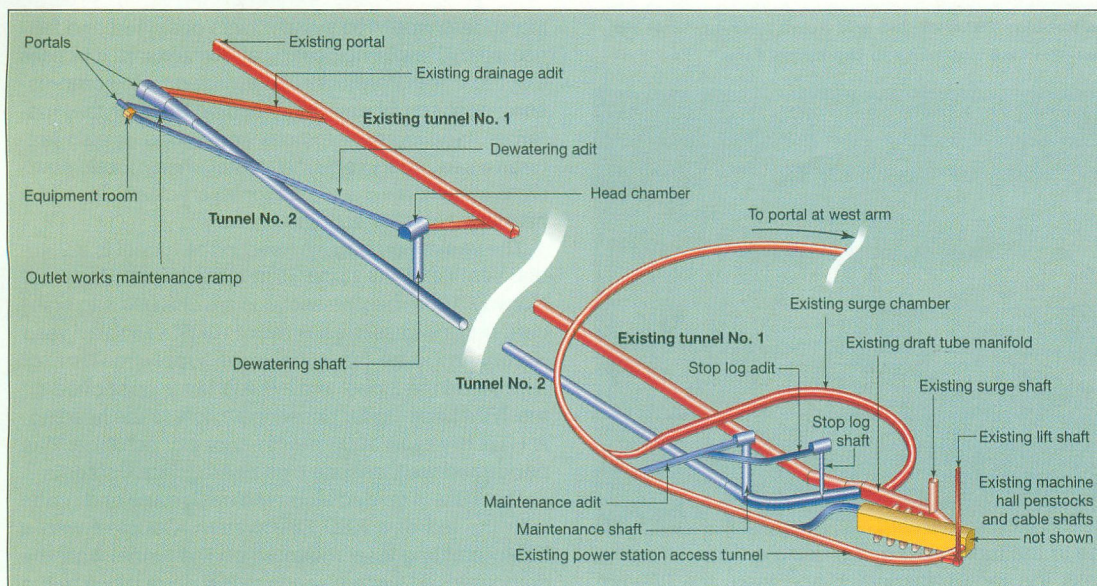
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Isometric depiction of the underground structures of the second Manapouri tailrace tunnel project



fully lined. A lining of either shotcrete or concrete will be installed as ground conditions dictate.

Other work, completed between June 1997 and July 1998, consists of drill+blast access adits, chambers and vertical shafts at the headworks and outlet works. Two 5m dia. horseshoe access adits and two 10m dia. work chambers (combined length 242m) provide access to the headworks from the existing power station access tunnel. The two headworks shafts consist of a 9m dia. x 51m deep maintenance shaft and a 3 x 10m by 45m deep stop log shaft.

Both shafts were excavated top down to the transition area using conventional equipment. The transition tunnel at the bottom of the shafts was excavated by top heading and bench methods. It is the connection point between the existing tunnel and the TBM tunnel and it houses a reinforced concrete stop log structure. Later in the project, a 15m long rock plug between the transition tunnel and Tunnel 1 will be removed during a 21-day outage of the power station. Before the outage, a temporary bulkhead will be installed in Tunnel 1 downstream of its junction with Tunnel 2 to allow the bifurcation area to be dewatered and permit the start of the outage works.

The ancillary works on the outlet works end of the project include a 358m long x 5m horseshoe dewatering adit, dewatering chamber and 7m dia. x 55m deep shaft which lead to an underground permanent dewatering system. Six horizontally mounted 560kW Flygt pumps will be used to dewater Tunnel 2 at a rate of 2000 litres/s via a 2.5m intake adit. The outlet works also consists of a stop log structure/reinforced earth wing wall structure, a permanent access bridge and tailrace channel improvements.

The cast-in-place stoplog structure was constructed at the portal within a steel sheet pile cofferdam. Larssen No. 6 piles were driven to depths of up to 14.5m through glacial and alluvial materials after the Rosenstock shock blasting process was used to pre-split the cobble and boulder laden strata. The

sheet pile cost saving programme was initiated by FDI under the value engineering change proposal clause of the contract where it replaced the original specified grouted curtain wall cut-off.

Geology

Tunnel 2 is located within Paleozoic metamorphic and igneous rocks of the Fjordland Complex. The metamorphic rocks consist mainly of gneiss, calc-silicate and quartzite and the intrusive rocks are composed of gabbro and diorite. Gneiss is expected for approximately 52% of the tunnel alignment. Mafic dykes and granitic intrusions intersect the formations as well. The ground is highly variable.

Uniaxial compressive strengths of the rock has been determined to be up to 226MPa. The rock mass is fractured to varying degrees and eight subvertical fault zones are expected to cross the tunnel alignment with subvertical dip angles. Two of the faults, the Wilmot and the Stella Burn, were bored through at the end of February. The overburden varies between about 100m at the portal to 1200m maximum.

Total anticipated groundwater inflow is 1300 litres/s with the most significant inflows expected within the first 3.5km of tunnel. Recorded hydrostatic pressures in the Disaster Burn fault during construction on Tunnel 1 were as high as 7.2MPa. Currently, total water infiltration into the bored tunnel is 70 litres/s.

The contract documents contain a geological baseline report which was created with the assistance of geological mapping and data from Tunnel 1.

TBM tunnel status

The 323-288 TBM was ordered by the FDI JV from Atlas Copco Robbins in February 1997 and was delivered to the Deep Cove wharf at the jobsite on April 10 1998, after a 13-month fabrication period in the Kvaerner-Markham plant in Chesterfield, UK.

The TBM drive began on June 12, 1998, one day ahead of schedule, down the 270m long, 12.5% de-

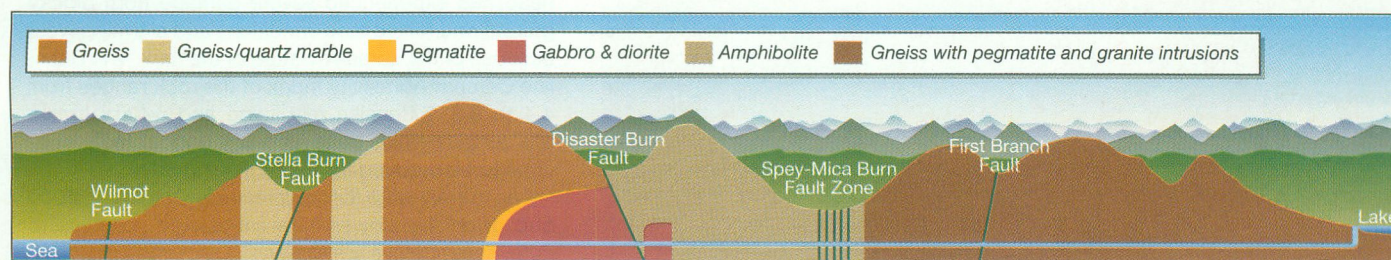
ON SITE

■ **CLIENT:** Electricity Corporation of New Zealand (ECNZ)

■ **DESIGN ENGINEER:** Woodward-Clyde/Design Power

■ **CONTRACTOR:** Fletcher-Dillingham-Ilbau

Fig 2. Geological profile of the route of the second Manapouri tailrace tunnel



The Robbins TBM323-288 and Rowa back-up 'walking' down the 12.5% decline to the tunnel face



Acknowledgements

The authors would like to acknowledge the team of individuals working to build this most important project. Likewise, the crews that built the power station in the 1960s deserve renewed acknowledgment. While the difficulties and challenges of constructing the second tailrace tunnel today are immense, they are surely only a fraction of those endured almost 40 years ago.

As part of a restructuring of the electrical industry in New Zealand, ownership of the Manapouri Power Station was transferred from ECNZ to a new company, Meridian Energy Ltd, on April 1, 1999.

cline to the tunnel low point, using articulated dump trucks for spoil transport. Since then, the 900mm wide, 800 tonne/h Continental-ACE tunnel conveyor system has been installed and commissioned. The belt is a steel cord belt and vulcanised splices are required after each 300 linear metres of TBM advance.

The conveyor system is equipped with two splicing stations, a fixed tripper or hold down station at the low point with the belt loop take-up, belt reeler, twin 450kw main DC drive assembly and transfer tower located at the tunnel portal. The transfer tower feeds a transverse conveyor bridge belt which carries the TBM spoil to the right bank of the existing Tunnel 1 channel way, where it is carted away by Cat 771 rock trucks for placement and contouring on the right bank. The cable stayed bridge is designed so that the conveyor bridge trusses also act as pipelines for pumping dirty water from the tunnel low point to a Svedala lamella clarifier/thickener water treatment plant.

The TBM back-up, a 470m long combination walk-

ing shoe/suspended system, was designed and fabricated by Rowa Engineering of Switzerland. It houses electrical transformers; cable reelers; air compressors; dust scrubbers (dry); heading booster fan; materials handling gear; offices and shops. It also features a secondary rockbolting station; a robotic shotcrete station; a vertical belt for invert clean-up; and a heading water de-sanding unit.

The ventilation bagline used in the tunnel is a 2.4m dia. Ventiflex PVC zipper joint system from Protan of Norway. 100m bagline sections are charged into standard bagline cassettes. A twin 110kW, variable speed Korfmann portal fan capable of supplying 41m³ of air/s feeds the tunnel and a 90kW fan is positioned on the TBM back-up for boosting air flow to the heading. A UTR dry type 1000m³/min capacity scrubber has performed well, despite high quartz silica contents.

The TBM is guided along the design line and grade with the aid of a ZED 261 system. Coupled with a beam-emitting laser mounted on the tunnel wall, the computerised system sends digital corrections to the TBM operator's console via an LED readout screen to guide the operator in correcting the machine's pitch, roll and yaw to maintain the proper alignment. Data acquisition on the TBM is provided by two Robbins CIC-200L data loggers.

At the time of writing, the TBM has advanced some 2.1km, or 22% of the total 9.6km. Average daily progress has been approximately 10m. This is significantly less than anticipated and is due to a number of factors which are the subject of ongoing discussions between FDI and ECNZ. Average rates of penetration since start-up are 0.8-1.5m/h. To date, best day and month figures are 30.4m and 431m respectively.

Water infiltration into the tunnel so far is around 70 litres/s, or about a third of the inflow encountered in Tunnel 1 at the same distance into the tunnel.

Ground support in the tunnel consists primarily of four basic contract-stipulated ground stabilisation types to accommodate the anticipated rock conditions. These types range from a minimum pattern of six 32mm dia. x 3m long epoxy coated, resin encapsulated bolts at 1.8m centres (Class T1) to 200 UC 46.2 (W8 x 32) steel ring sets at 1.2m centres, with a 10mm WRF mesh used as a lagging support between the sets (Class T3). To date, 81% of the tunnel has been supported with T1 support and 9% with T3 steel set support (155 sets), the balance have been a combination of T1A and T2 ground classes. The T2 class is a pattern of full perimeter rockbolts, WRF mesh and 75mm of non-reinforced shotcrete.

The contract also contains provisions for the installation of 9m long spile bars, supplementary rock support measures such as heavy and light channels, WRF mesh, additional bolts and shotcrete as well as provisions for drilling probe holes, 125mm drain holes and formation grouting.

The most significant down-time issues so far have been ground support delays and cutter changes/cutterhead wear and damage delays. These have accounted for over 40% of tunnelling time. The cutterhead has experienced severe damage from blocky ground and mixed face conditions and alarming wear because of the abrasive nature of the rock. The Baseline Cerchar Abrasivity Index of the rock ranges from 4.4 to 6.2. Extensive rebuilding and refurbishment has already been done and will undoubtedly continue to be required for the remaining drive.

The current date for completion is October 1, 2000 but, given the slower than anticipated progress to date, some delays are likely.

TBM Robbins 323-288 specifications

Supplier	
TBM	Atlas Copco-Robbins, US
Trailing gear	ROWA, Switzerland
Machine diameter with new cutters	10.1m
Main bearing	Three roller (3-roller)
Cutters	Series 17 (432mm)
Number of disc cutters	68
Maximum recommended individual cutter load	267kN (27 tons approx.)
Cutterhead	
Recommended normal operating thrust	18156kN (1816 tons)
Cutterhead drive	Electric motors/air clutches Gear reducers
Cutterhead power	3465kW (11x315kW)
Cutterhead speed	5.07 rev/min (high), 2.5 (low)
Approximate torque (high speed)	6344KNm
Approximate torque (low speed)	9516KNm
Thrust cylinder boring stroke	1.8m
Gripper pads	
Size of pads	6.5x2m each (2)
Maximum pressure on tunnel wall	2.5MPa (25 tons/m ²)
Machine conveyor	
TBM	1370mm
Capacity (approx)	1388m ³ /h
Belt speed	122m/min
Weight (approx.)	
TBM	925 tons
Weight of TBM including trailing gear (approx)	1500 tons
Heaviest piece	96 tons
Length of TBM	25m
Length of TBM including trailing gear	495m

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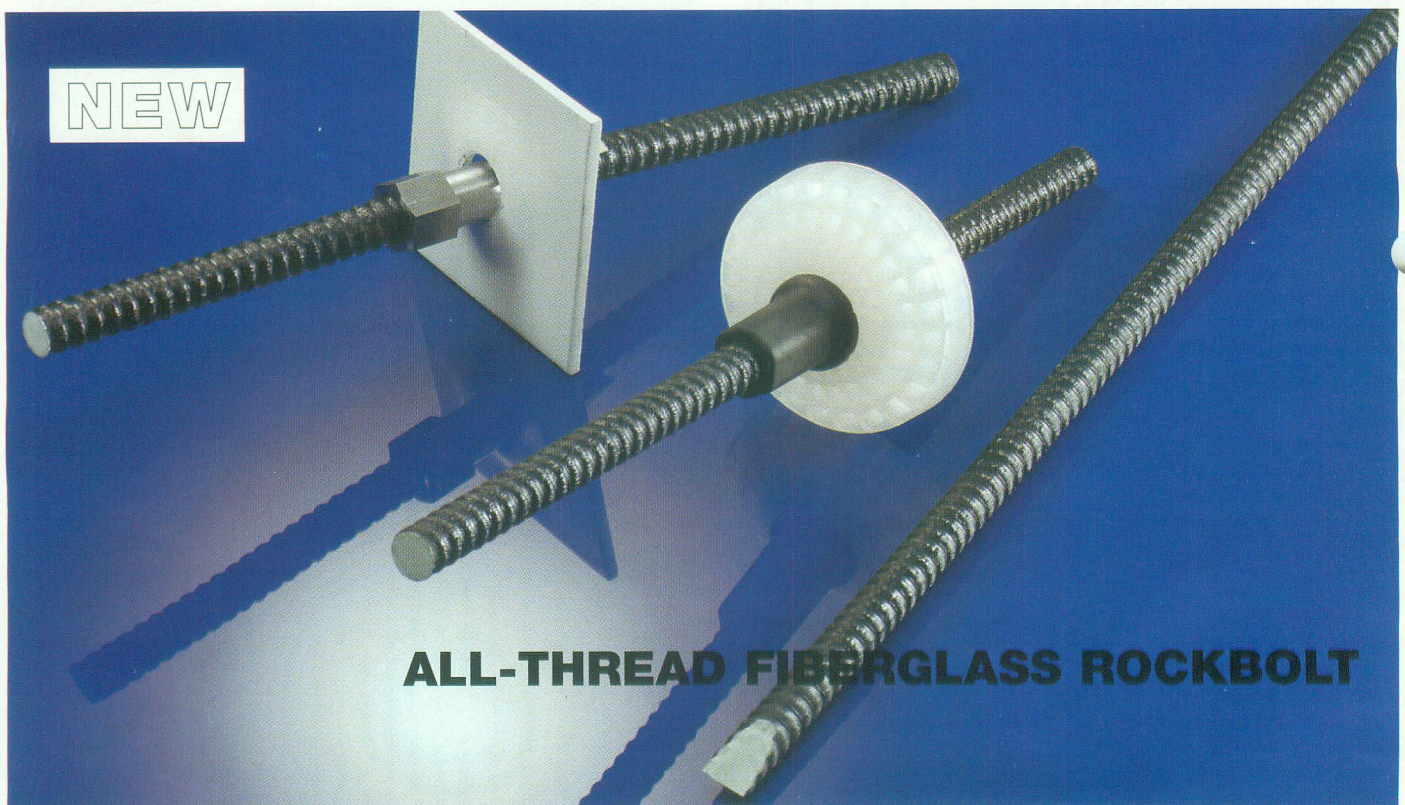
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Immersed tube tunnels – Øresund

The immersed tube tunnels of the Øresund Link between Denmark and Sweden represent one of the world's largest tunnelling projects. The fact that senior representatives from the owner, consulting engineer and contractor appeared on the same platform before the job was complete testified to the success to date of this mammoth project. Presenters at the February 18 meeting were: Steen Lykke, Øresundkonsortiet; Cees Brandsen, Tunnel Engineering Consultants v.o.f. (TEC); and Per Nielsen, Øresund Tunnel Contractor

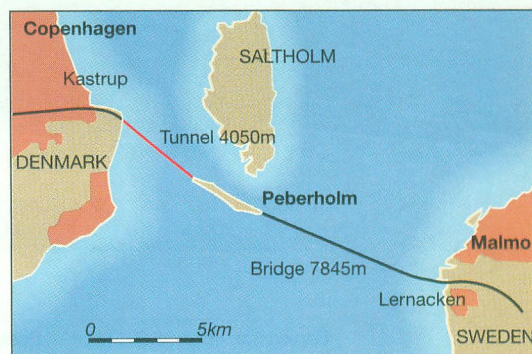


Fig 1. Location of the Øresund immersed tube tunnel

The remarkably large scale of the Øresund immersed tube tunnel project was conveyed by all three speakers. The presentation opened with an account from a representative of the owner. Steen Lykke explained that Øresundkonsortiet was 50% Danish and 50% Swedish, as befitted the location of the project. The two contracts for which he was responsible had a combined value of approximately \$406.3bn.

Fig 1 illustrates the location of the 16km link. The initial 3.5km of immersed tube tunnel are located on the Danish side. This stretch leads to a man-made island comprising some 10 million m³ of material, three quarters of which was obtained from the seabed. The immersed tunnel requires 20 reinforced concrete box elements each 176m long and a staggering 38.7m wide. Each tunnel element is divided into eight 22m long segments.

Lykke explained that the owner was required to establish a framework for the project team, to define a timescale and to identify the services to be procured. The three main principles which guided the contract philosophy were:

- To have a design+build contract
- To employ known technology
- To adhere to EU procurement requirements

Design+build allows the contractor's design to take account of his particular experience and equipment. It also leads to clear responsibilities and division of risks between owner and contractor.

In accordance with EU procurement rules, the contractor 'with the most economically advantageous tender' was selected. Contractors were not allowed to *qualify their tenders*, thus enabling a clearer comparison between tenders during the evaluation process. For this reason, a pre-tender seminar was held for prospective contractors.

In relation to contract management, Lykke stressed the importance of defining and communicating clear objectives. He raised a few eyebrows in the audience by acknowledging that the contractor knows best 'sometimes', and by stating that the owner and con-

tractor should strive to be 'ahead of each other'.

The project employs some 120 owner staff and a similar number of consultant personnel in an integrated team. He felt that this level of staffing was necessary to avoid 'being run over by the contractor'. A further challenge to the owner's team was to deal with the ever increasing expectations of the authorities in terms of scheme provision.

Lykke considered that only two of the following three success criteria could be priorities at any one time:

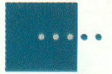
- Quality
- Time
- Cost

Initially, the owner's representatives focused on quality and time, but their focus was currently on time and cost. The owner needed to look ahead continuously to the next problem in an environment of continual change. Owner relations with the contractor were based on: principles of co-operation (not confrontation); openness; respect; incentives (for example an early opening bonus); and fairness.

On behalf of the designer, Cees Brandsen opened

Fig 2. Construction programme for the Øresund immersed tube tunnel

Description	1995	1996	1997	1998	1999	2000
Design and planning	[Bar spanning 1995-1998]					
Facility design and construction	[Bar spanning 1995-1996]					
Portal and ramps	[Bar spanning 1996-1998]					
Precasting of elements	[Bar spanning 1996-1998]					
Immersion of elements	[Bar spanning 1996-1998]					
Earthworks on the west island	[Bar spanning 1996-1998]					
Earthworks on peninsula	[Bar spanning 1996-1998]					
Tunnel finishing works (fireproofing, cladding, asphalt)	[Bar spanning 1998-1999]					
Closure joint	[Bar spanning 1999-2000]					
Partial access from peninsula to the west island	[Bar spanning 1999-2000]					
M & E	[Bar spanning 1998-2000]					
Install communication and signal	[Bar spanning 1998-2000]					
Track laying Kastrup Station - Tunnel portal (ASO Railway)	[Bar spanning 1998-1999]					
Track laying in the tunnel (Balfour Beatty)	[Bar spanning 1999-2000]					
Track laying on the west island and catenary works (BV-1)	[Bar spanning 1999-2000]					
Test and commissioning	[Bar spanning 1999-2000]					
Completion of works on the Øresund Link	[Bar spanning 2000]					
Owner's test and commissioning	[Bar spanning 2000]					
Start of operation on the Øresund Link	[Bar spanning 2000]					



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Overall view of the casting complex for the Øresund immersed tube tunnel

by showing a cross section through the immersed tunnel units, which contain a pair of two-lane road traffic carriageways and two separate single overhead electrified rail tracks. He claimed that TEC's design gave improvements for the owner over and above the concept design in terms of:

- The environment - by reducing the expected coastline land take for the scheme
- The technical solution - by a risk analysis approach to optimise the design, particularly M&E aspects
- The aesthetics - by integrating the scheme with the existing levels of the nearby airport at Copenhagen
- Cost - by reducing the original structural thickness requirements

The comprehensive use of electronic communications and scanning made the management of correspondence and drawings easier. With the owner, contractor and designer in one office, Brandsen claimed that "everyone spoke with the voice of the owner". This was particularly remarkable given that the project team was multi-national and included Swedes, Danes, British, Dutch, and French, each nationality having its particular behavioural traits.

He noted that the contractor was obliged to self check its work, with the consultant making only spot checks. Overall, he felt that quality was managed very well, although "not perfectly". After immersed tunnel element 13 sank, procedures were reviewed and some were changed.

While none of the speakers gave details of the form of contract, Brandsen did describe how variations were managed, drawing attention to the importance of ensuring that they were clearly defined and understood, and that payment was implemented rapidly following their acceptance. He concluded by mentioning that the scheme had given rise to numerous innovations.

Speaking for the contractor, Per Nielsen explained that Øresundkonsortiet comprised five companies: NCC; E Phil & Son; John Laing Construction; Boskalis Westminster; and Dumez-GTM. STM was its consultant.

Nielsen's slides served to illustrate the enormous scale of the civil works. His contribution stressed the following features unique to this project:

- An incremental cast and launch technique
- Full section casting
- The use of a gravel bed foundation on the sea floor

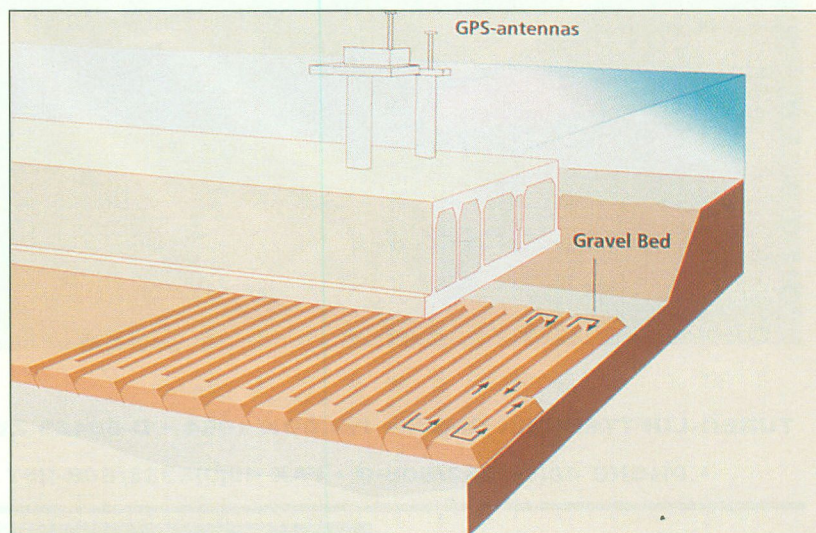
Fig 2 summarises the construction programme (page 67). Started in 1995, the contract is scheduled to end by the summer of 2000 and is presently running two months ahead of schedule.

An overall view of the casting complex is shown above. Immersed tunnel components are moved from the covered casting bay, out into a shallow basin for outfitting, then to a deep basin ready to be towed out past the floating gate. Each 22m segment, requiring 2700m³ of concrete, was poured in approximately 30h.

Nielsen explained that in the casting shed there were six hydraulic rams with a total pushing capacity of 3000 tonnes for the 55 000 tonne tunnel elements. The push force was kept as low as this by using Teflon on epoxy coated concrete. The scale of this

"On the whole, quality was managed very well, although not perfectly. After immersed tunnel element 13 sank, some procedures were changed"

Fig 3. Immersed tunnel components were installed on the seabed within a level tolerance of +/-15mm



task was truly monumental, but just as impressive was the arrangement to pump in 1 million m³ of water into the basin before removing the 45m wide floating gate.

He also explained the method of installing the immersed tunnel components on the seabed within a plus/minus 15mm level tolerance, a lower figure than that specified (Fig 2).

Plainly, there is much more of the technical detail of the Øresund Link project to be reported as its con-

struction draws to a close. Nevertheless, as an account of the organisation of the immersed tube tunnel contract and a summary of its excellent progress to date, the British Tunnelling Society was privileged to receive this presentation, given in perfect English by speakers for whom English is not their native tongue. It was also notable that no-one in the audience dared question whether this truly remarkable civil engineering feat was really a tunnel in every sense of the word!

Discussion

The first of a number of lively discussion points from the audience came from **Mike Senyard**, who asked how the 22m long elements were joined up. It was explained that there was a shear joint connection and prestressing was employed. In reply to a subsidiary question, it was explained that the gravel was levelled very shortly before installation of the units.

John Dale of Kvaerner Construction asked about the owner's involvement in the safety regime and how multi-national communication problems were overcome. Lykke answered by stressing that they had drawn heavily on safety issues arising from the neighbouring Storebaelt project, and also the owner demanded that health and safety was specifically addressed in all method statements. Interestingly, he added a general observation that the official au-

thorities did not necessarily assist the promotion of health and safety excellence.

Regarding communications, it was noted that the labour force was actually 100% Scandinavian, and the multi-national technical supervisory team worked together as professionals. In response to **Mike McConnell** of Balfour Beatty Major Projects, who followed up on this theme regarding the effectiveness of the quality process in practice, Brandsen admitted that it had taken time to get a quality system operating satisfactorily. Nielsen remarked that paperwork was anathema to Scandinavians, but in spite of this the quality of the work itself was up to scratch!

In response to **Mike Bennett** of Bennett Associates, it was explained that water pressure was used to effect the seal between adjacent tunnel units and that requirement to place the tunnel completely beneath present seabed level overcame the buoyancy problem.

Nielsen assured **Colin Reed** of Halcrow that, in the contractor's opinion, the owner was a competent organisation. Replying to **Tom Murphy** of the CTRL Project, the speakers explained that the tunnel had been designed to withstand high intensity fires, and only vehicles containing liquid gas and certain other highly volatile substances would be banned from transit.

Gareth Davies of Symonds Group commended the project's engineers for the innovative choice of sliding the units using jacks, to which the speakers added that this had indeed been a difficult and brave decision. He was disappointed only in that the considerable international contingent did not appear to include Welsh speakers, and posed the question as to whether the industry could now contemplate much longer immersed tube tunnels. Having to deal with ventilation was identified as the only real constraint.

Rapporteur: Peter Jewell

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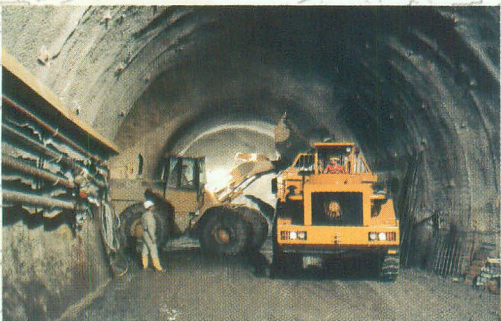
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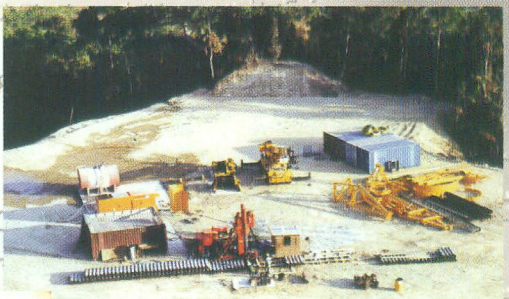
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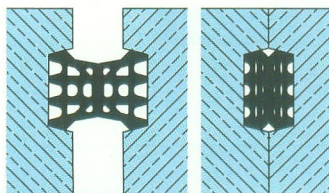
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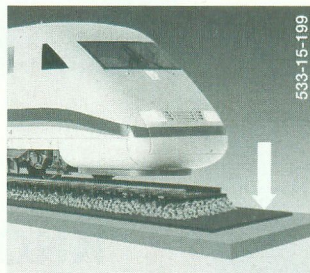


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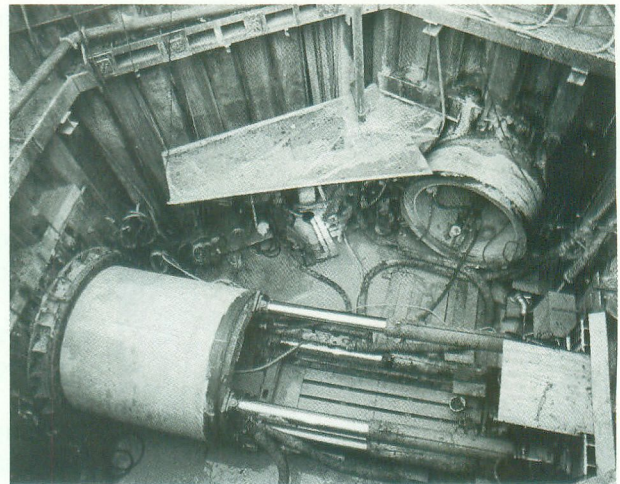
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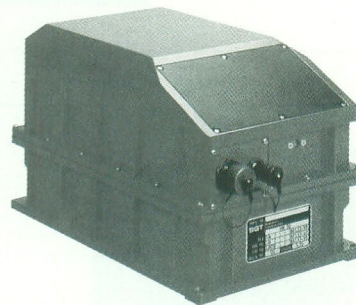
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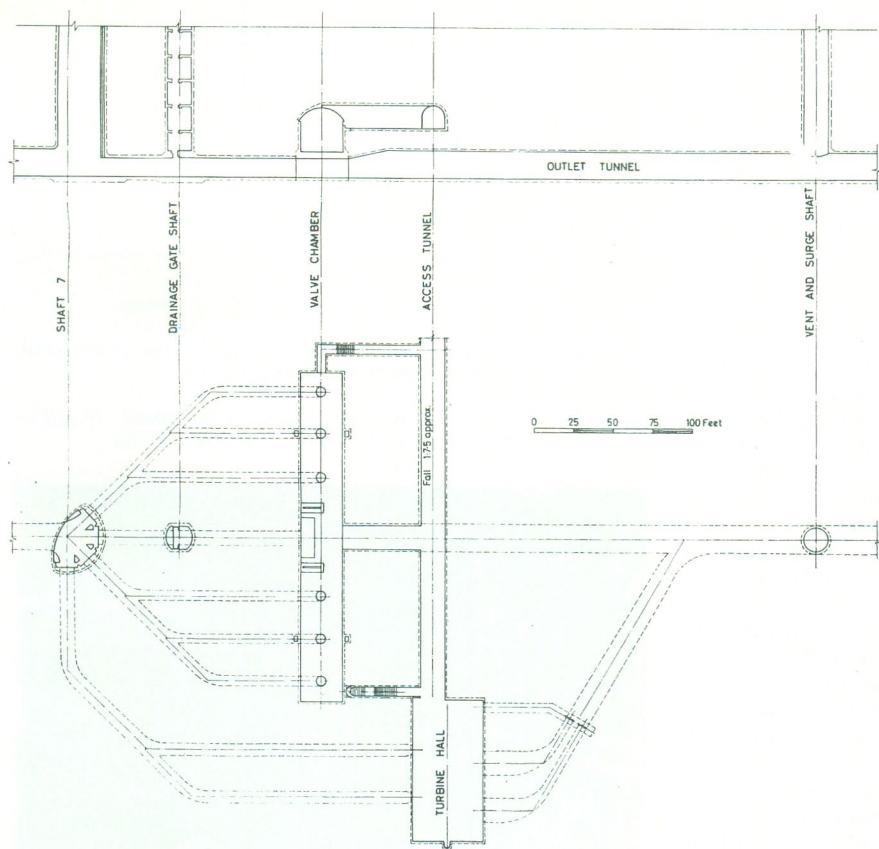
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Orange-Fish tunnel

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W. H. Cooper
F.I.C.E., M.S.A.I.C.E.

Project Director
Orange-Fish Tunnel
Consultants, Johannesburg



Left: General arrangement of underground works.

Agricultural and, more recently, industrial expansion in the central and South Eastern part of the Republic of South Africa is limited by the amount of water available. Investigation into sources of water for this area started many years ago but it was only in July 1962, that a Government White Paper was produced reporting on the proposed Orange River development project. This multi-purpose scheme provides irrigation and industrial water and has beneficial social implications of providing employment and raising the living standards of the non-white population in this area. This vast scheme was originally outlined under six phases, due to take some thirty years to complete. This programme has subsequently been amended and the precise timing of the various major works is not yet finally settled. In addition, greater emphasis has been placed upon the hydro-generation of electricity in the initial stage.

At the present time work is proceeding on the construction of the Hendrik Verwoerd dam, the Orange-Fish tunnel and some of the distribution canals. The construction of the P.K. le Roux dam was temporarily held back in October 1967 on economic grounds. The dam and the tunnel are being constructed under contract and supervised by independent consulting engineers. The distribution canals are being built by the Construction Division of the Department of Water Affairs of the Republic of South Africa.

Tunnel site investigations

Serious site investigation for the tunnel first began in 1948 when the then Department of Irrigation put down some exploratory boreholes along the selected tunnel line and carried out some surface surveys. Further drilling programmes have been undertaken and the total footage of core recovered from all holes approaches 100,000 lin. ft. Some of these boreholes were over 1,500ft in depth. These have provided information on the nature of the sedimentary rocks of the Beaufort Series to be traversed and the incidence of the numerous dolerite sills and dykes. Further to expand the knowledge of the rock types four exploratory adits were driven, two near the tunnel inlet and two about twenty miles downstream, where it was hoped to intersect some of the

weaker mudstone rocks without having to go to too great a depth. In addition to the geological examination of cores and laboratory testing of hand specimens, in-situ jacking tests were carried out in the adits themselves to assess the moduli of deformation of the various rock types. One adit was driven into a large dolerite body at the intake to ensure its suitability for concrete aggregate.

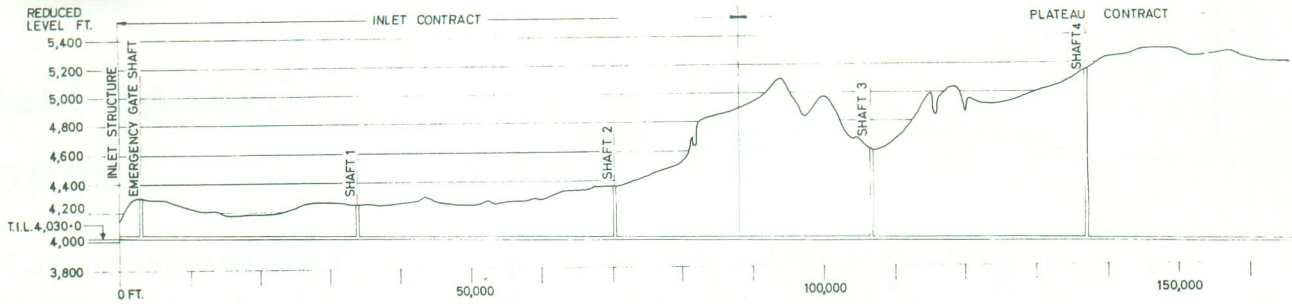
A policy decision was taken that the standard of accommodation on construction for both White and non-White personnel would be kept as high as possible and, in view of the isolated location of the working sites, this was indeed a necessity if a very rapid turnover of personnel was to be avoided. With this in view, separate contracts were awarded for the construction of three townships, one at each end of the proposed tunnel line and one at its mid-point. These townships have purified water reticulation, waterborne sewerage, electric light, tarred roads and very adequate recreation facilities.

Fifty-one miles long

The tunnel will be over fifty-one miles long. An investigation of the proposals indicated that seven working shafts were required for efficient excavation. These sites were selected and joined by a new system of eighty miles of tarred roads, which also connect with adjacent stations on the South African Railway system.

The object of the tunnel is to divert water from the Orange River, where floods of over 400,000 cusecs are not unknown, into the valley of the Great Fish River and, at a later stage, also to the valley of the Sundays River. Consideration of existing bed levels and of the anticipated water levels in the reservoir showed that the physical gradient of the tunnel could not be much steeper than 1 : 2000. The maximum flow requirement through the tunnel is 2,000 cusecs and from consideration of this and the flows needed at low reservoir levels, an internal diameter of 17ft 6in was ultimately fixed. Apart from frictional considerations, the rock types through which the major part of the tunnel runs make it essential that the tunnel should have a concrete lining.

For all but a few months in mid-winter when the river flows



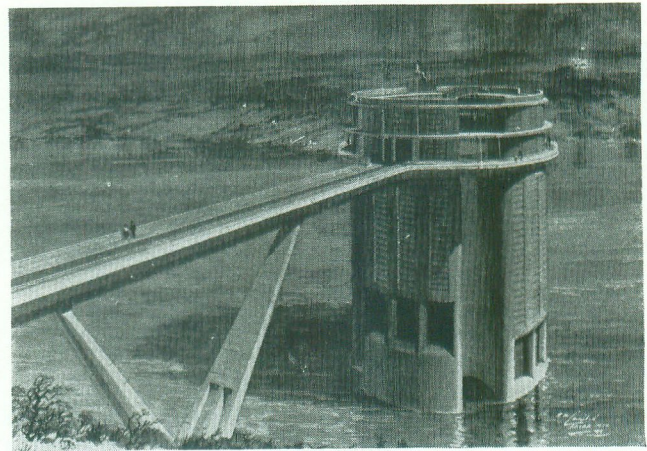
are very low, the Orange carries a solids load of $\frac{3}{4}$ per cent to $1\frac{1}{2}$ per cent. It is inevitable that over the years the reservoir will be subject to heavy siltation and the intake works have been designed with this in view. In the initial stage the intake tower can draw off water at four different levels and two other intakes, not meanwhile to be made operational, are provided in the first stage of the tower, which can ultimately be heightened if required. The control gates in the tower are provided only to dictate the level at which water is abstracted. The flow through the tunnel is regulated at the downstream end to ensure that it flows full at all times.

Model tests on the reservoir area adjacent to the tower were carried out by the consulting engineers in the Department of Water Affairs' laboratory in Pretoria to determine the optimum location to avoid silt density currents, etc. In addition, a photo-elastic analysis was carried out on structural models of parts of the tower at Nottingham University.

Because of the great length of the tunnel, the use of the water as a means of power generation is somewhat limited. At very high flows virtually all the head is absorbed in friction and no power is available at the outlet end. With little more than half the maximum flow through the tunnel and with the reservoir full, the energy available is of the order of 10 mega-

Above and facing page: Longitudinal section of the Orange-Fish tunnel, more than fifty miles long.

Below: An impression of the intake tower for the tunnel. It will be over 200ft. high with a 300ft. long access bridge.



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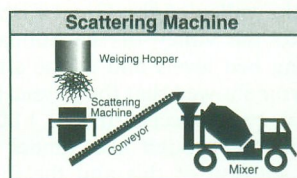
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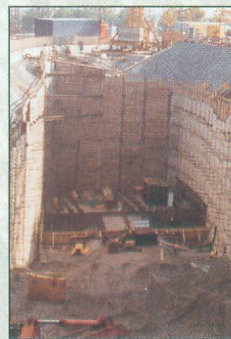


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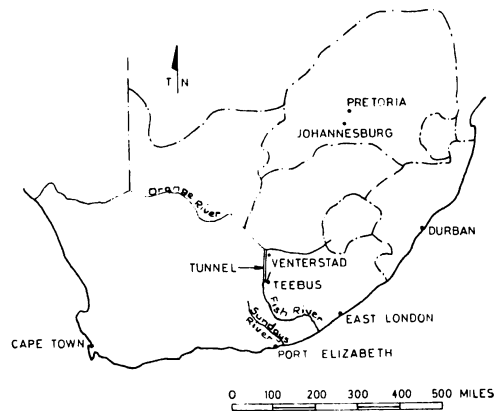
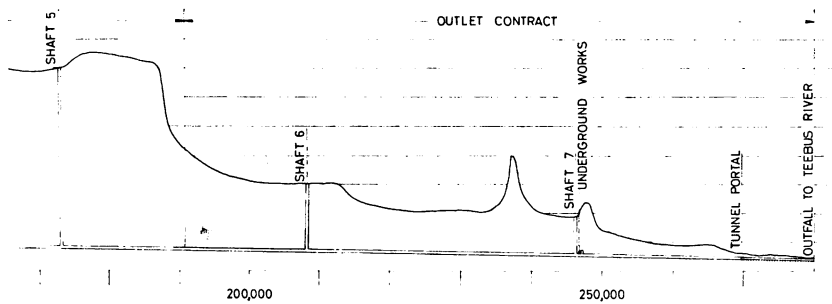
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Tunnels and Tunnelling, May 1969



Right: Location of the tunnel.

watts. An economic outlet for this very fluctuating amount of power is not easy to arrange, but provision is being made initially for a small generating set with space for larger plant at a later date if necessary. Dependence in the early stage for energy dissipation has to be placed almost entirely on hydraulic equipment. Flow will be regulated and energy destroyed through a bank of ported sleeve valves, for which tests were carried out in the British Hydro-Mechanics Research Laboratories at Bedford. These control works are located adjacent to No. 7 shaft, i.e. approximately 47 miles from the tunnel intake. Downstream of this point the rock cover to the tunnel rapidly decreases and to have sustained the reservoir pressure over this section would have required a steel or reinforced-concrete lined tunnel with consequently higher costs. The tailrace tunnel downstream of the control works at shaft No. 7 is however designed to run full under all flows, that solution proving less costly than a free flow tunnel.

At the outlet portal a distribution structure will be built by means of which the water can be made to flow either into the Teebus Spruit and thence to the Fish River or into a canal system shortly to be commenced, by means of which the area in the more immediate vicinity can be irrigated. The outfall to the Teebus River has been designed to minimise erosion of the river channel and has been model-tested in the University of the Witwatersrand, Johannesburg.

Three contracts for main tunnel

The construction of the main tunnel has been divided into three contracts. Each covers approximately one third of the length of the tunnel. The inlet contract (upstream) also includes the intake tower and the access bridge, while the outlet contract covers all underground works at shaft No. 7 and the outfall canal etc. The centre section consists of three shafts from 500 to 1,500ft deep and the associated tunnel works.

The works were tendered by firms selected from an international list of candidates. The inlet contract was awarded in January 1968, to a consortium comprising Batignolles, Paris; Cogefar, Milan and African Batignolles. The outlet contract was awarded in July 1968 to a consortium of Dipenta, Rome and the Johannesburg Consolidated Investment Company. The plateau contract was awarded in October 1968 to a consortium consisting of L.T.A. Ltd., Johannesburg; Boyles Brothers Drilling Company, U.S.A.; Boart and Hard Metal Products, Johannesburg, and Compagnie de Constructions Internationales, Paris. The total value of these three tunnel contracts as awarded is £32,500,000.

Construction progress

The trickiest feature of the inlet contract is that the work on Hendrik Verwoerd dam started well over a year before the tunnel contract was awarded. If very expensive cofferdam arrangements are to be avoided the intake tower must be complete with its access bridge up to operating floor level and the inlet drive of the tunnel must be finished and sealed off before there is any danger from flooding as a result of impounding in the reservoir, which could occur any time after mid-1970. To date the tower excavation has been completed

and the concrete work has already reached the level of the tunnel invert (4030). The inlet drive of the tunnel is now almost a mile long, being worked from a short adit to the west side of the intake tower. After the normal teething troubles of an overseas contract in an isolated area, work is now gaining momentum on this face. This contractor elected to drive inclined shafts at a 15deg slope rather than sink the vertical shafts covered by the contract. These shafts are completed and driving from all four faces at these shafts should be well under way by the middle of 1969.

On the outlet section surface excavation on the canal etc. has begun, as has the sinking of the necessary construction and gate shafts. The access tunnel to the underground works is also well advanced.

The sinking of all three shafts on the plateau section has commenced and the performance figures on this work are anticipated with some eagerness since the organisations comprising this consortium are well to the fore in shaft sinking records in South Africa.

The presence of numerous, if dispersed, bodies of dolerite has discouraged any of the contractors from adopting a tunnel mole for the excavation work. Each consortium, however, has its own preferred methods and plant and it will be very interesting to see in the course of this large project, how the different types of approach to this problem compare.

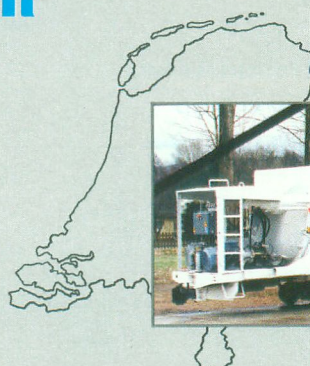
The planning and execution of the Orange River project is under the direction of the Department of Water Affairs of the Republic of South Africa and thanks are due to the Secretary for Water Affairs for permission to publish this article. The Consulting Engineers for the Orange-Fish Tunnel are Sir William Halcrow & Partners, London and Keeve Steyn & Partners, Johannesburg, acting in consortium as Orange-Fish Tunnel Consultants.

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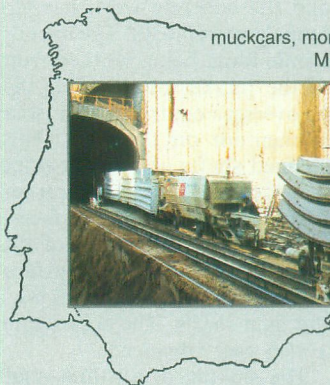
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Qinling: China's longest rail tunnel

An account of construction on the Qinling rail tunnel is given by Li Doanhuang, Chief Engineer at Xian-Ankang Railway Construction headquarters, Ministry of Railways.

The Qinling Tunnel, located in the north section of Xian-Ankang railway, is the longest railway tunnel under construction in China. It is also the sixth longest single-track (standard gauge) railway mountain tunnel in the world, and comprises of two roughly parallel single-track tubes, 30m apart. They are the Qinling 1 tube, with a length of 18.46km, and the 18.456km long Qinling 2 tube. The Qinling Tunnel has a cover of 870m at the Xian portal in the north and 1025m at Ankang portal in the south.

The tubes have roughly the same longitudinal gradients: a 11% incline for the first 14.7km long section running south from the north portal; and a 3% decline for the remaining 3.2km leading to the south portal. Both the north and south portal sections are located on curves with a radius of 500m.

The Qinling Tunnel runs approximately south-north. It passes through the east-west facing Qinling Mountain. The tunnel is located at a depth of more than 1000m, with a maximum of 1600m, in a 3.8km long section. Qinling Mountain, which separates the Yellow River and the Yangtze River, slopes steeply and has deep gullies and a waterfall on the north side, and a gentle slope, plenty of rainfall and a developed water system on the south side.

Geology

The geology along the tunnel consists mainly of hard rock, which includes medium jointed compound gneiss with fractures, high ground stress and rock bursts in the first 4.2km long section; migmatitic granite with developed joints and faults, high ground stress and rock bursts in the second 2.3km long section; compound gneiss with undeveloped joints and

frequently occurring rock bursts in the third 7.7km long section; and jointed migmatitic granite with green minerals in the last 4.3km section (Fig 1).

Both tubes will accommodate electrified rail lines, for which an elastic monolithic track bed and jointless track have been adopted. The Qinling 1 tube is being excavated by two open type TBMs and supported by primary shotcrete, bolts and secondary cast-in-situ, with a precast segment for the invert. Minimum i.d. is 7.7m.

The Qinling 2 tube has a horse-shoe shaped section and will be constructed by drill+blast and supported by primary shotcrete and bolts and secondary cast-in-situ concrete (Fig 2). Construction is as follows: a central tunnel, which will serve as a parallel pilot for the Qinling 1 tube, was excavated by drill+blast and will be enlarged to form the Qinling 2 tube after completion of the Qinling 1. The central tunnel, with a finished height of 6.2m and a width of 4.8m, accounts for 66% of the total excavation volume of the Qinling 2 tube. It will provide information on the geology, drainage, construction ventilation and construction transportation for construction of the Qinling 1 tube. It is supported by shotcrete and bolts.

The Qinling 1 and 2 tubes are connected by cross passages at 420m intervals. In both tubes, large safety chambers are sited at 120m intervals and small ones at 60m intervals. The cross passages and the chambers will be excavated by drill+blast.

Construction of the pilot tunnel for Qinling 2 tube started from both the north and south portals on January 18, 1995. After 36 months, the No.1 construction Bureau of the Ministry of Railways, on the north side, came to the contract boundary on January 18, 1998, having excavated 9 505m. The maximum monthly

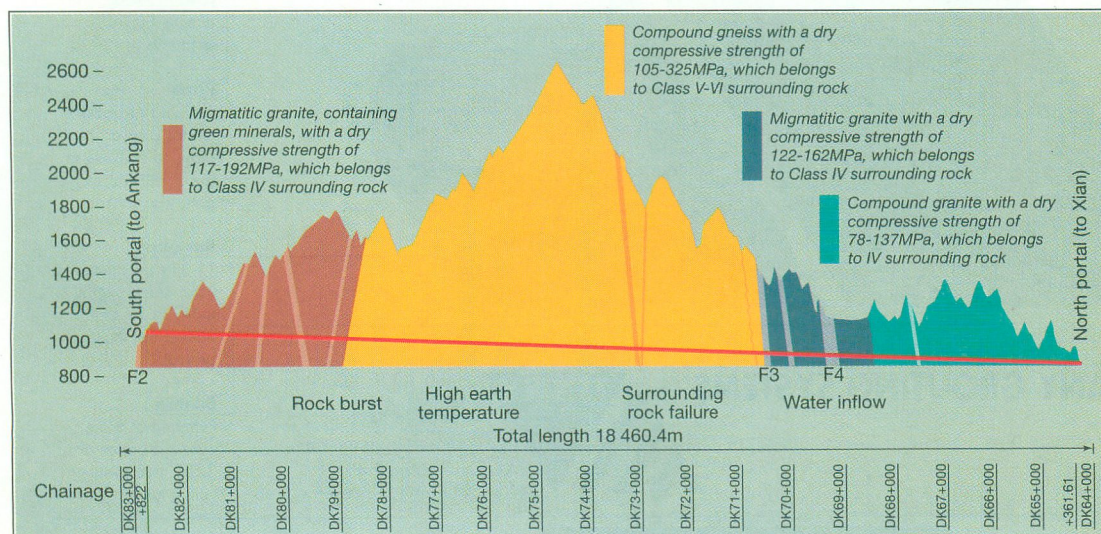


Fig 1. Geological profile of the Qinling Tunnel

rate was 456m and the average, 264m. On the south side, the No.18 Construction Bureau of the Ministry of Railways reached the boundary on March 10, 1998 after 37.6 months and excavating 8591m. The average monthly rate was 238m.

Construction of the pilot for Qinling 2 has been the fastest for a railway tunnel built by drill+blast in China. Errors in line and level were just 12mm and 1mm respectively, well within the requirements of the Regulations on Tunnel Survey, and construction quality matched the Acceptance Standards.

Two TBMs imported from Wirth in Germany are being used to excavate the Qinling 1 tube from both sides. Construction started on December 18, 1997 on the north side and on February 16, 1998 from the

south. Up to December 20, 1998 the TBMs had excavated 2807m on the north side and 3462m on the south.

The main reasons for the slow advance on the north side were:

1. The hard and intact compound gneiss has caused heavy wear of the cutter rings, 1010 rings have been used so far – three times as many as used in the migmatic granite on the south side
2. Replacement of cutter rings takes too long
3. Repair of the cutterhead takes more than 20 days.

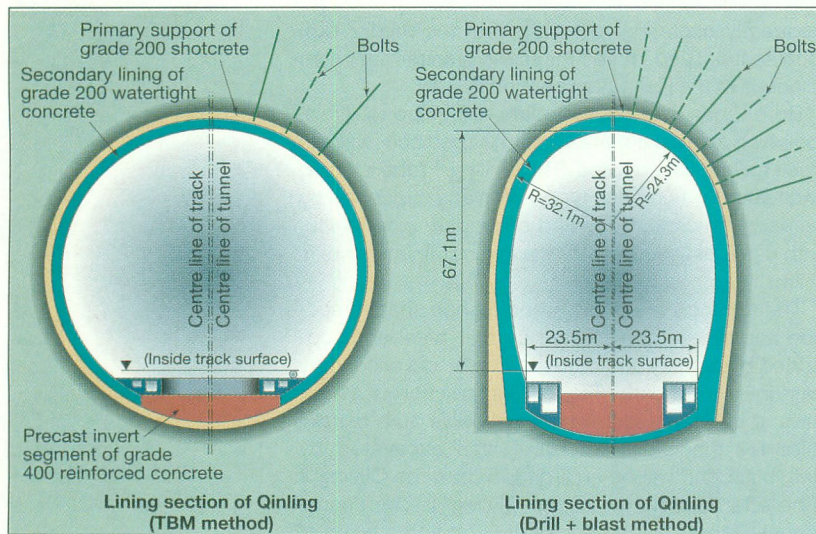
According to the Xian-Ankang Railway construction schedule, the Qinling 1 tube should hole through by October 1, 1999. However, since the current TBM advance rate is not able to meet this schedule, the intermediate part (6.5km long) which is accessible from the Qinling 2 pilot tunnel has to be excavated by drill+blast in both the southward and northward directions. Only in this way will the Qinling 1 breakthrough meet its target date, so that the Xian-Ankang Railway can be commissioned by 2001.

Update

Up to March 30 this year, the south and north TBMs had excavated 4370m and 3680m respectively. TBM construction from the south portal is proceeding smoothly, but the drive from the north has experienced some problems. From March 5 until the end of that month, this TBM made little progress. First it had a small fault in the electrical system, then the oil in the hydraulic pressure system was found to be polluted. The problems are now understood and both the Chinese Ministry of Railways and the Wirth company are working to ensure that the TBM construction work will be finished on schedule.



Fig 2. Cross section of the Qinling Tunnel



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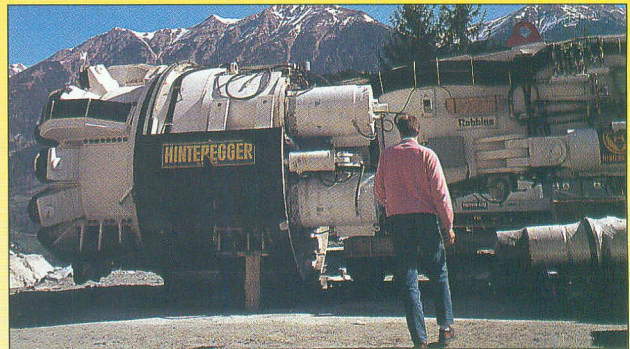
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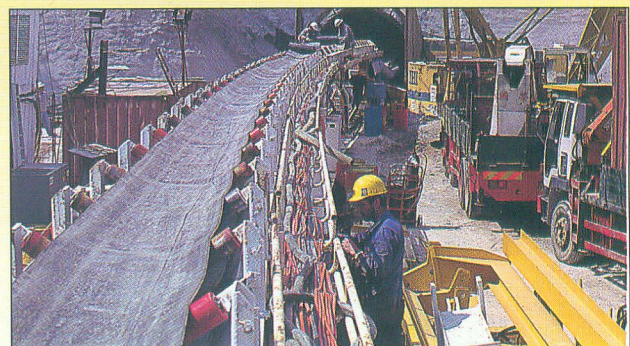
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Scanner for tunnel surveying and recording

Demands for quality management and documentation of underground construction projects are still increasing and development of high-tech systems increases in parallel. Measurements taken by photogrammetric and geodetic means can today be performed on an almost fully automatic level. Dipl. Ing. Dr Helge Grafinger, ILF Consulting Engineers, Innsbruck, Austria, Geodetic Engineering & Development, explains how the DIBIT tunnel scanning system works.

Conventional methods for recording the geometry of a tunnel during advance and after completion are limited to individual points, which are either selected because of their geometric location (regular grids) or because they comprise a distinctive feature (arches, rockbolts). Thematic data such as rockbolts, cracks, ingress of water or specific geology are generally registered visually, with subsequent written documentation in a protocol. As a rule, there is no relation between the geometric and thematic data, nor is it possible to guarantee comprehensible documentation.

DIBIT is a tunnel scanner which eliminates these defects and is able to record the tunnel surface both geometrically and as an image.

System concept

Requirements specific to the application: The idea of the tunnel scanner is based on the stereo-photogrammetric recording of the tunnel surface in combination with a geodetic determination of the position of the cameras in order to obtain the pertinent three-dimensional co-ordinates of the surface points in the co-ordinate system of the project. This means that all of the tunnel surface that can be recorded by the camera are registered simultaneously from two different positions in order to enable a 3-D reconstruction.

In the tunnelling industry, such a system has to meet the following requirements:

- Short recording time
- Simple operation by one person who does not need to have any special qualifications
- Robustness under the tough conditions prevailing during the advance of the tunnel
- Accuracy of the geometry within a range of +/- 10mm
- Easy and quick evaluation
- Clear and varied possibilities for representing the results

Therefore, DIBIT is based on the following specifications:

- Use of high resolution CCD cameras as recording sensors
- Use of a motorised, self targeting, programmable theodolite for positioning the cameras
- Use of a portable PC suitable for outdoor use
- Use of powerful image processing modules for a fully automatic evaluation

A short description of the three components of DIBIT recording, evaluation and analysis follows.

Recording module: the recording module consists of two CCD cameras and three glass prisms rigidly

mounted on a robust frame of carbon fibre. The cameras simultaneously record a stereoscopic pair of images of the tunnel surface. The glass prisms are used to determine the position and orientation of both cameras. Positioning is done by a servo-theodolite. The tunnel scanner and theodolite communicate via radio modem, which allows the theodolite to be operated in a completely automatic manner. The frame can be rotated through a horizontal axis.

A tunnel section is generally recorded in five partial sections of the profile. A portable PC serves as recording computer for controlling the recording process and storing the measured data. The individual components are mounted on a tripod. The total weight is approximately 18kg.

A halogen spotlight is necessary for illuminating the tunnel surface. The field computer can operate for 40 mins off batteries. For permanent use, an external power supply is necessary.

For recording, the recording module is placed in the centre of the cross section, with the measuring frame positioned at right angles to the tunnel axis. The approximate position is entered in the field computer. Then the sector to be recorded is selected and the automatic measuring process is started. It takes about 40 seconds to record one sector.

Evaluation module: The recorded image data are transferred from the field computer to the evaluation computer. After the area to be evaluated is selected, the evaluation software calculates the 3-D co-ordi-

DIBIT-Recording module field computer with camera frame on tripod



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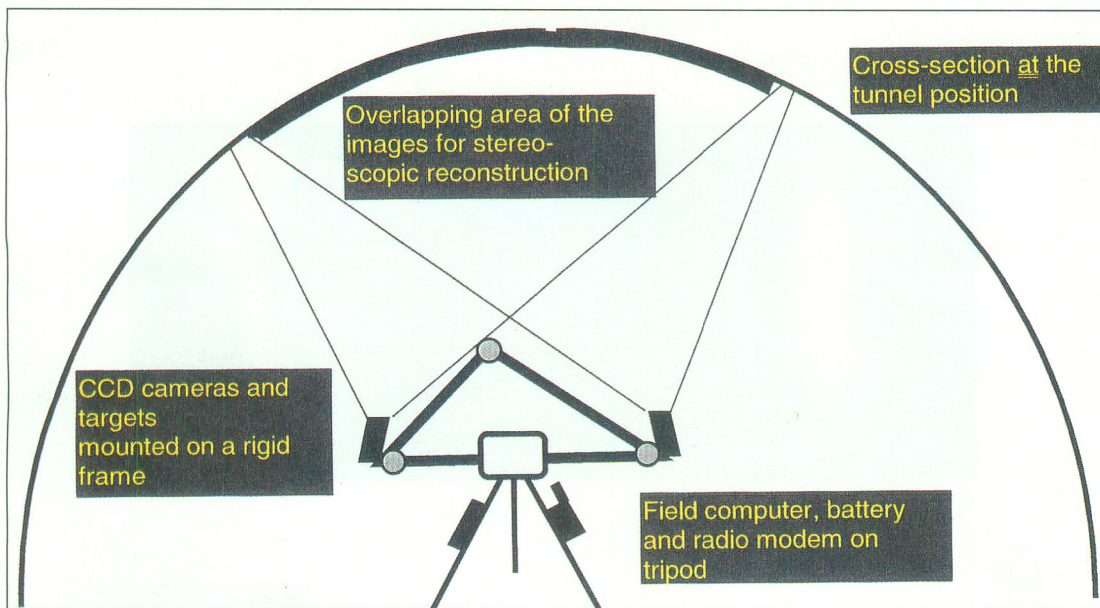


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Schematic of the recording process of the tunnel scanner for the crown area

nates of all image points in a grid of up to 10 x 10mm and produces rectified images referring to the nominal geometry. The software components required are: the so-called matching, that is, finding correlating points on both images and storing the image co-ordinates; calculating the co-ordinates of these points by means of the camera parameters, the co-ordinates of the glass prisms and the pairs of image co-ordinates; and joining the individual rectified images to an overall image of the tunnel surface.

The combination of optimised calculation modules and currently available hardware enable an evaluation velocity of 2 mins/stereoscopic pair of images. The required memory capacity is 2MB for a stereoscopic pair of images, 33MB for the corresponding intermediate results and 1MB/tunnel meter for the resulting image, including space model (3-D co-ordinates).

Analysis module: the analysis module is used to represent results and process them for further applications. In detail, the following are necessary:

- All recorded construction phases, e.g. initial excavation, shotcrete lining, deformed shotcrete lining, secondary lining, are available as image documentation and can be analysed on screen
- Simultaneous provision of the 3-D co-ordinates allows additional calculations
- Comparison of nominal and actual tunnel profile (overbreak/underbreak)
- Comparison of the profiles of two construction phases (thickness of shotcrete/of in-situ concrete)
- Comparison of different images of the same construction phase (deformations)
- Calculation of the difference in volume of two construction phases (shotcrete consumption, rebound)
- Calculation of the spatial orientation of geologically relevant area (bedding, joints).

Possibilities for more far-reaching applications include:

- Export of co-ordinates to different CAD and graphics programs for visualising the geometric situation
- Elaboration of as-built records
- Data import of additional information in order to be integrated into the as-built records

Applications

Recording of the profile during advance: after each round of advance (e.g. heading, bench, invert) recordings can be made of the excavation, i.e. the visible rock surface. This is usually done after completing the mucking process and before placing the arches and

wire mesh. The area as far as half of the tunnel diameter behind the working face has to be available for the recording activities for approximately 5 mins. The apparent time loss for the advance work can largely be compensated for by the temporal restructuring of preparatory work for the subsequent phases.

Documentation of the working face: the digital images of the working face are used for geological documentation. They are obtained at the same time as the documentation of the tunnel intrados. Recording is carried out with a distance of one tunnel diameter between the camera and the working face in less than one minute.

The result is a 3-D model of the geological structure of the working face. It can be used for calculating the spatial orientation of the bedding and the joint planes as well as for the exact allocation of the morphology. In combination with the images of the tunnel intrados it is then possible to construct a geological model of high quality, which can subsequently provide valuable findings for the evaluation of stability.

Documentation of the profile before and after placing the secondary lining: this is performed as a series of images of the profile in mass production. Without taking into consideration the time necessary for the preparation and measurement of the co-ordinates of the theodolite, the tunnel scanner can be used to record tunnel lengths of up to seven times the tunnel diameter /h. The time needed for the evaluation of such an area is approximately 3h.

Scanning in existing tunnels: another interesting area of application for the tunnel scanner is the status quo assessment in existing tunnels. The resulting data provide the essential basis for comprehensive documentation and subsequently for an economical solution of rehabilitation tasks, enlargement of the profile and so on for long term operation of the tunnel.

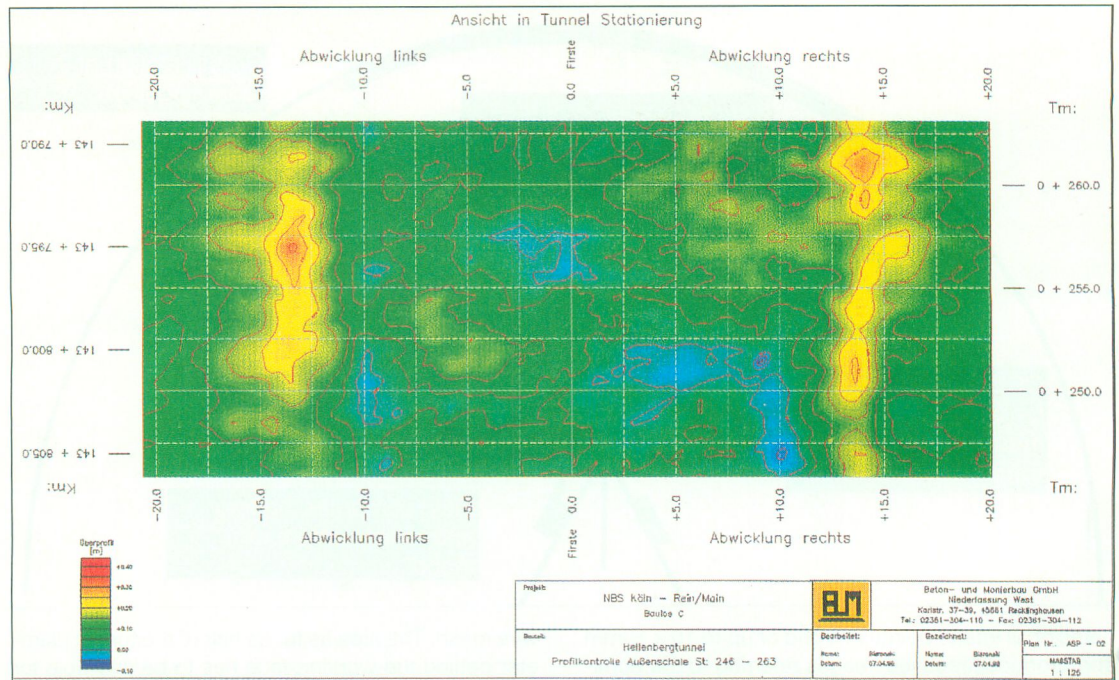
Representation of results: the results of the tunnel scanner are presented in three ways:

- Graphic depiction as cross section
- Graphic depiction as an image (rectified orthophoto) projected on to the nominal profile
- Numerical description of geometric and thematic resulting data

The geometrical location of the tunnel surface is emphasised by means of a super-elevation factor in the depiction of the profile; in the orthophoto by means of the depiction of contour lines of the distances to the nominal profile; and by means of colour-

“Another interesting area of application for the tunnel scanner is the status quo assessment in existing tunnels”

Example of resulting graphic digital elevation model of primary lining



“It is interesting to compare recordings, such as those of the initial excavation with those of the shotcrete lining”

ing. Thus, the image and the digital spatial model of the tunnel lining of the different recording phases are available simultaneously.

It is interesting to compare recordings, such as those of the initial excavation with those of the shotcrete lining, or those immediately after shotcrete lining with those five or ten days later. The combination of different digital images can be extended as desired, enabling material thickness, volumes and deformations to be registered and depicted in various ways.

Uses to date

DIBIT has already been used on more than 20 different tunnel projects, some of which are detailed: some are shown in Table 1.

1. Arlberg railway tunnel for Austrian Federal Railways: status quo assessment of the 100-year-old tunnel for the design of a new track in the eastern portal zone
2. Selzthal Tunnel, Austrian Motorway: continuous documentation of excavation and shotcrete lining during the advance, final documentation of the secondary lining
3. Hellenberg Tunnel, German Railways: overall digital image of the shotcrete lining after completion of the advance for the preparation of trimming works and optimisation of the secondary lining

4. Copenhagen Metro: documentation of the segmental tunnel lining of the TBM sections advanced to date for design of the final track line

5. New railway line Nuremberg-Ingolstadt, German Railways: continuous documentation of the advance for quality control of the support measures and basis for accounting for geological overbreaks

Advantages for contractor and client

For the contractor the most important areas of application are the following:

- Quality control of his own tunnelling crews: it becomes apparent at once to what extent overbreak is caused by inexact drilling or improper mechanical excavation. The accuracy of the profile including support measures can also be checked
- Quality control of construction material: actual shotcreted volume can be determined and consequently a comprehensive calculation of rebound. This is of great importance for the evaluation of changes in the mix formula and when applying shotcrete
- Preparation of work: comprehensive knowledge of the actual profile provides a much better basis for planning future work and costs

Advantages to the client are first and foremost the following:

- Objective proof of quality and performance: the system provides data which enable compliance with contractual stipulations to be controlled. The time of recording is registered and is entered in the shift documentation
- Increased information value of deliberations on tunnel statics: in the event of special problems it is now possible to use the actual thickness of the shotcrete as the basis for deliberations on tunnel statics
- High quality as-built drawings: it is possible to call up all data by mouse click for any part of the tunnel and to depict them visually. All as-built data not depicted on the CCD images of the support measures are additionally integrated into these new as-built records of the tunnel. All data comprise an objective basis for evaluating additional claims by the contractor.
- Improved geological documentation.

Advantages for the contractor and the client are optimised when use of the scanner is specified at tender stage by the client and the contractor charged with the execution.



Future outlook

Progress in the field of digital image observation will inevitably increase and the following scenarios are envisaged for this tunnel scanner:

- An acceleration of the recording process will be achieved with the next generation of motorised, self-targeting theodolites
- Accuracy can be enhanced by increase in the resolution of digital cameras
- Increased use of image processing techniques will provide additional means of interpretation and thus guarantee a greater degree of pre-

processed resulting data

- Improved visualisation of the resulting data will be possible with the relevant software and increasing hardware capacities
- All data from the tunnel scanner can be integrated into spatial information systems – which partly exist already – in combination with calculation, accounting and statics data, etc.

To date, the system discussed has shown that using digital image processing and modern surveying systems constitutes significant progress in the documentation and quality assurance fields of tunnelling.

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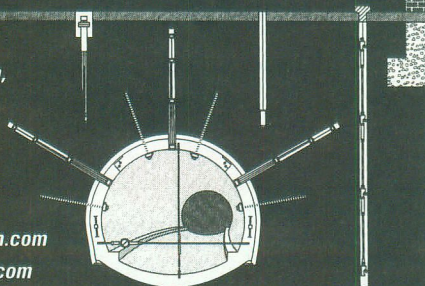
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CONTRACTS & ORDERS

Dragages wins Hang Hau Station MTRC contract

Dragages et Travaux Publics (HK) Ltd has won a US\$168m contract for construction of the Hang Hau Station and associated tunnelling works as part of the extension to Hong Kong's MTR network to link Kowloon with the new town of Tseung Kwan O. The contract (Contract No. 601) was awarded by the Mass Transit Railway Corporation (MTRC) and includes construction of Hang Hau MRT station, underground structures for six residential towers, technical buildings and 1.2km of cut+cover tunnels on either side of the station. Work on the project is scheduled for completion in September 2002. Dragages is currently engaged on projects awarded by the KCR West Rail Extension that include the Tai Lam Tunnel and the Kwai Tsing tunnels.

Balfour Beatty wins Contract 440 on Channel Tunnel Rail Link

Union Railways South, a subsidiary of London & Continental Railways has appointed Balfour Beatty Major Projects as the successful contractor for East Kent, the last civil engineering contract on Section 1 of the Channel Tunnel Rail Link. The \$119m contract (known as Contract 440) is for the construction of 16km of CTRL that includes 2 million m³ of earthworks and two cut+cover tunnels. All civils contracts on Section 1 of the CTRL are now let, with construction on schedule for completion in 2003.

Gammon-Kvaerner chooses Keller in Hong Kong . . .

UK company Keller Ground Engineering's Manufacturing Division has supplied Gammon-Kvaerner with two CP1000 paddle assisted colloidal grout mixers, two weight batching systems and two air powered agitation tanks for use on the Strategic Sewage Disposal Scheme in Hong Kong. Gammon-Kvaerner's contract involves 9km of deep tunnelling from Kwum Tong to Stonecutters Island. The equipment will be used for grouting the projected tunnel line where water and/or broken ground have been identified.

. . . and Gammon wins piling contract

Gammon Construction has also won a US\$49m piling contract on the Tseung Kwan O extension in Hong Kong for the Mass Transit Railway Organisation. The contract involves the installation of 500 bored piles and associated earth-works.

JV for German underground railway station

A structural engineering JV between the Buro Happold German operation, Happold Ingenieurbüro, Berlin, and Leonhardt, Andra und Partner, Stuttgart, has been formed to undertake the underground redevelopment of Stuttgart 21 Main Station. The client is DBProjekt Stuttgart, a sister company of the German rail organisation Deutsche Bahn. The underground station has an unconventional design and is part of an overall plan to accommodate the new 400m long Eurotrains that will pass beneath the city. The main feature of the design is a sculptural concrete shell resembling an organic structure, which forms the roof and columns of the new station.

Indian companies scoop Bhutan work

Altogether, five civil engineering contracts have been awarded by the Tala Hydroelectric Project Authority (THPA) for the Tala scheme, all of which include underground work. The \$400m project is a joint effort between India and Bhutan and is situated on the Wangchu River in Bhutan. The work includes a flushing tunnel to remove sediment, a 22.7km long headrace tunnel and an underground powerhouse. The major contract winners are Hindustan Construction Co. of Mumbai and Jaiprakash Industries of New Delhi. The contract packages are understood to be as follows: C1- a 6km headrace tunnel, intake and desilting system, and a damn worth \$77.7m, awarded to Hindustan Construction; C2- a 5.2km headrace tunnel worth \$22.8m, awarded to Jaiprakash Industries; C3- a 4.4km headrace tunnel worth \$21.3m, awarded to Larsen & Toubro; C4- a 7.1km headrace tunnel worth \$31.3m, awarded to Hindustan Construction; C5- an underground powerhouse complex worth \$77.2m, awarded to Jaiprakash Industries.

Mühlhauser makes multiple orders

German company Mühlhauser, the mining equipment manufacturer and specialist contractor, has received orders from all around the world in recent months. They include: supplying the Cartellone del Peru in South America with equipment that includes rota-dump cars and a rota-dump system for work on the 9.6km Chimay hydroelectric project tunnel. In the Netherlands, the company has orders to supply contractors with segment cars, mortar boxes and remixers for work on the Sophia Tunnel which is part of the Betuweroute rail link between Rotterdam and the German border. It has also received substantial orders from a variety of contractors in Singapore for a wide range of equipment that will be used on the North East Line of the Singapore Metro/MRT.

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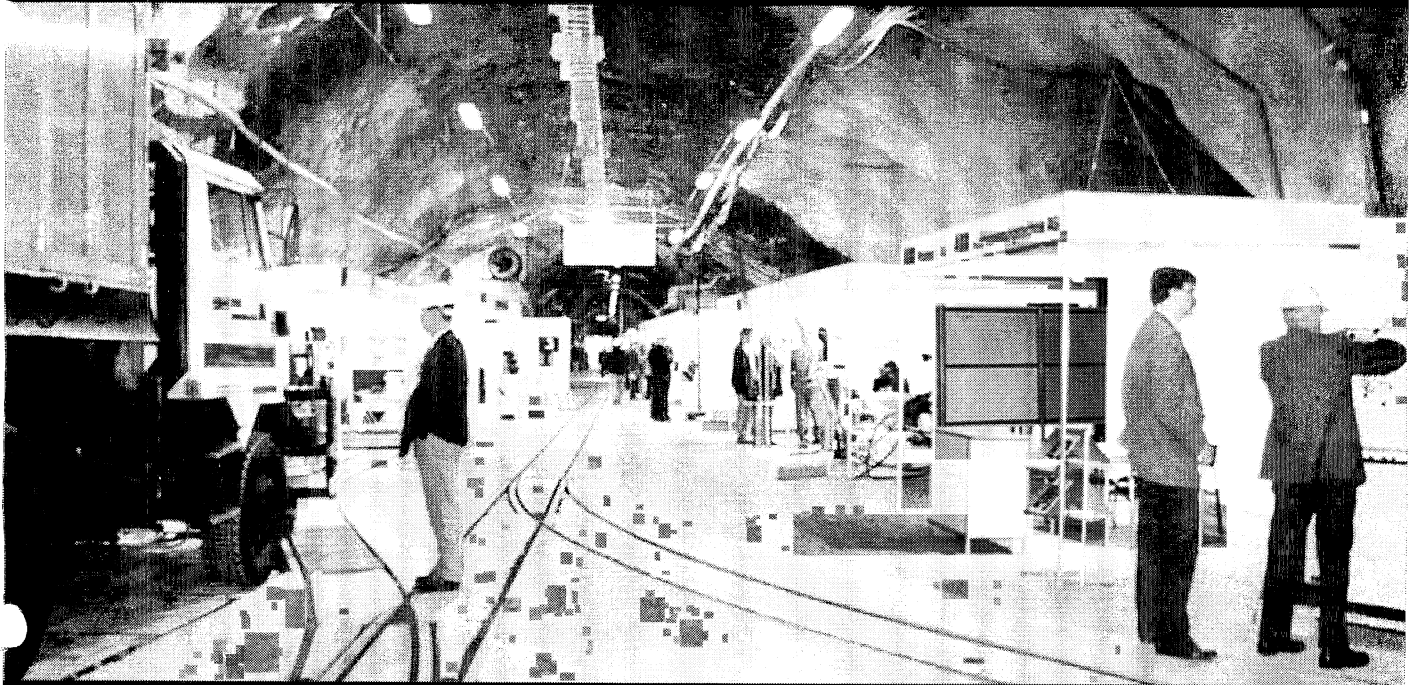
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Down hole hammer

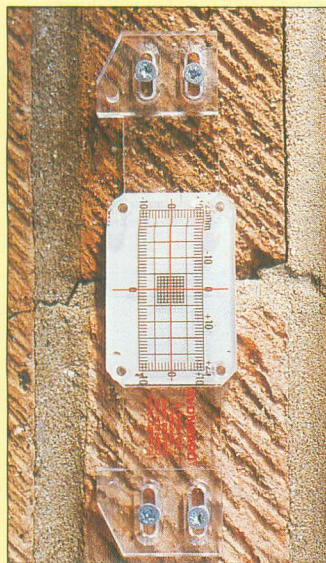
Halco Drilling International has launched its new Halco Dominator 600 HF, a down-the-hole hammer for blast hole drilling, water bores and civil engineering applications. The DTH hammer will drill at speed in medium to soft rock and broken ground conditions, where normal hammers run the risk of becoming stuck.

CONTACT:
TEL: +44 1422 399910

Crack monitoring

Avongard supplies a kit that contains all you need for setting up a crack monitoring system using calibrated Tell-Tales. The kit contains a crack width gauge for measuring and recording crack widths before starting monitoring. The five 'Plus' calibrated Tell-Tales can be used for monitoring the opening and closing of the gaps as well as shear movement.

CONTACT:
TEL: +44 1275 849782



Optimising rock fragmentation

MOCAP has developed a moulding stemming plug that optimises rock fragmentation during blasting, curbs noise and flyrock, and holds down costs. The easily fitted Vari-Stem plug confines blast energy to the borehole, resulting in the need for fewer boreholes, and improved safety standards. Stemming movement has been recorded as being 100% better than regular stemming, with injection velocity improvements of 40%.

CONTACT:
TEL: +44 1952 670247

Large axial impellers



Elta fans UK is to launch a new range of large diameter axial impellers with diameters ranging from 1250mm to 2000mm. Blade arrangements come in 3, 6, 9 or 12 blades. Typical airflow performance for the 2000mm dia. model is 108m³/s at 870 rev/min. Suiting

typical 50 and 60Hz direct drive motors or indirect drives, speeds of 1750 rev/min are achieved on the 1250mm dia. model. The impellers will be available through Elta Fan companies and distributors.

CONTACT:
TEL: +44 1489 566500

Flexible shotcrete

CMS Pozament has introduced CEMROK 4WS, a pre-blended wet spray concrete material. It has been developed to offer safer working environments for operatives.

CEMROK 4WS is a flexible general purpose material that is ideal for repair and refurbishment jobs, especially where dust problems are an issue.

CONTACT:
TEL: +44 1283 554800

Compressor range expands

Atlas Copco has added seven new models to its Series 6 portable compressor range. The units offer normal working pressure of between 7 bar and 14 bar, with free air delivery rates of between 105-185 l/s. The new models are available for 7 bar; 10.3 bar; 12 bar; and 14 bar operation. Three of the compressors utilise a water cooled, turbo-charged 4-cylinder Deutz 1012 generation diesel engine, while the other four are powered by an intercooled version of the Deutz engine.

CONTACT: TEL: +44 1304 368688



New excavators and loaders

Case has unveiled a new range of excavators and wheeled loaders – the Alliance hydraulic excavator family and the C series wheeled loaders. The series includes the 90 series hydraulic excavators, the C series wheeled loaders, the Case 88 series hydraulic excavators and the Case backhoe loader range. The Case Compact Family includes the Maxi range of mini hydraulic excavators, The Case skid steer loaders and Case trenchers.

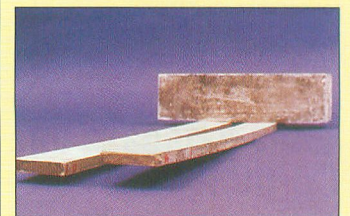
CONTACT:
TEL: +44 1235 522770/1

Pre-cast rings for quick manholes

The new Milshaft pre-cast concrete rings is used for rapid manhole installation in most ground conditions. Milshaft rings are available in most standard depths and can be used in the construction of jacking shafts for microtunnelling.

CONTACT:
TEL: +44 1795 425191

Reducing concrete shrinkage



Geace Construction Products has developed a liquid concrete admixture that reduces concrete shrinkage. Eclipse Shrinkage Reducing Admixture, when incorporated into the concrete mix at the rate of 2% by weight of cement, reduces shrinkage by up to 80% at 28 days and up to 50% at one year and beyond. Eclipse is compatible with most other admixtures and additives.

CONTACT:
TEL: +44 1548 521623

Power breaking

The Model HM1303 Breaker from Makita is an upgrade to its powerful Hammer range. The 14kg machine offers an improved power to weight ratio. Increased power provides higher performance and a lighter weight reduces operator fatigue.

CONTACT:
TEL: +44 1327 341366

Power Carrier tips on the move

With an overall width of 700mm the HTC500D Power Carrier from Aces is capable of passing through an open domestic door, turn in its own length, and carry up to 500kg of material. The hydraulic circuit gives the facility to tip on the move, and provide power capable of driving most hand tools. The chassis is able to accept alternative equipment; such as a trencher, fitted to its mounting points.

CONTACT:
TEL: +44 1452 830101

Conveyor belt slippage reduced

The new Flex-Lag Rubber Pulley Lagging from Flexco helps prevent conveyor belt slippage in a wide range of operating conditions, reducing the causes, problems and subsequent maintenance costs of poor belt/pulley traction. The product is available in a choice of two water-shedding tread designs and two rubber compounds. The rubber Flex-Lag designs, diamond-pattern and plain-pattern tread, offer water and material-shedding effectiveness with abrasion resistance and friction coefficient for specific conditions.

CONTACT:
TEL: +44 1282 770040

Tools database on CD-ROM



Cimsources, the German software company has produced an information system CD-ROM that combines the product spectrum of 14 of the world's leading tool manufacturers. The huge, easy to apply material database for workpiece material allows for cross-reference and covers 13 national standards. Tools and related spare parts are described identically allowing the user to process the tool data and export all true scale drawings to NC-programming or simulation software.

CONTACT:
TEL: +49 241 88870

Directional drill modified

American Augers, Inc. has announced the production of the DD6, a model based on the successful DD-5 self-contained directional drill. The DD-6 displays high levels of thrust and pullback, and rotary torque.

The DD6 features the same

mechanised pipe loading system as the DD5. Pipe is held in a basket containing nine sections of 5m long. A total of 18 sections of pipe can be loaded onto the drill at any one time.

CONTACT:
TEL: +1 419 869 7107



Concrete handling and delivery

The Magnum Metro RH 80/28 from CIFA is a truckmixer-pump with a 28m boom, four sections, "ZED" folding system and a mixer of 7 cubic meter. All the Magnum models have longitudinal pumping unit with a flow rate of 64m³/h. Also from CIFA is the Maxcrete, a concrete remix surge hopper, designed to accept concrete from transport vehicles and provides remix capabilities and feeds concrete to pumps, conveyors or buckets.

CONTACT:
TEL: +39 02 354761

Xenon beam to light the way

A new small, lightweight and virtually indestructible light, is available in the UK through Sea & Sea Ltd.

Designed for industrial use these tough, rugged and fully waterproof high intensity xenon beam torches are capable of outperforming lights of similar size.

Just 133mm long, the UK4AA, T2 tested torch comes with a range of handy helmet clips and accessories to enable adjustable hands free illumination

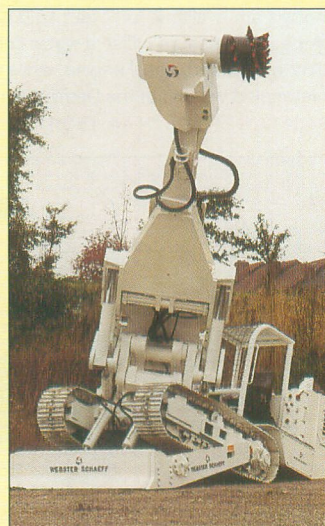
CONTACT:
TEL: +44 1803 663012

Bearings for US roadheaders

Fag UK Ltd has supplied bearings on the four WS2000CS Webster Schaeff Roadheaders being used on the Boston Harbour contract in the US. Fag taper roller bearings are being used on the cutting heads and Fag spherical roller bearings are sited at the base of the boom arm.

According to the manufacturer, its taper rollers bearings were selected to accommodate the combined axial and radial loads experienced by the cutting heads, while its spherical roller bearing at the base of the boom arm offers excellent radial load performance in support of the movements of the cutter arm.

CONTACT:
TEL: +44 1952 208100



Directional tooling and accessories

StraightLine, a US manufacturer of horizontal directional drilling systems, offer a wide range in downhole tooling. The new patented Fourth Generation III drill heads feature a centre line positioned cutting bit, providing the optimum engagement angle for cutting, reducing torque and increasing the performance of your drilling system.

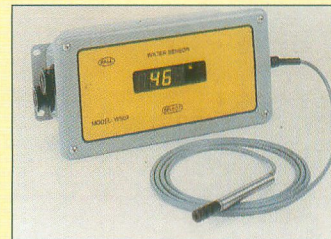
Radial flow reamers provide excellent performance in sands, small aggregates, light shale and clays. Internal fluid ports within the reamer wing position fluid jets to provide a pre-cut soaking action.

CONTACT:
TEL: +1 316 283 5511

Detecting water contamination

The Pall Water Sensor is designed to detect water in solution in lubricating oils, fuel oil, hydraulic fluids and dielectric fluids. An LED displays percentage saturation, temperature or both, alternating every few seconds. At 90% saturation it will flash to draw attention to the water contamination level. A fitting is supplied to allow direct connection to a fluid line. The Pall Water Sensor comes with a 2m probe cable and weighs only 2kg.

CONTACT:
TEL: +44 1705 302225



Safety & Security product catalogue

The latest publication from Portasilo, Safety & Security: Product Catalogue 1999, features safety, security, storage and containment products. The new Total Package Drum Handling and Storage Systems, Spill Containment Systems, Data and Fires Safes and Window Security System are among the product range in the catalogue. This publication enables products to be bought straight off the page and facilitates hire of products direct from the manufacturers own hire fleet.

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DATES & EVENTS

May 29-June 3 General Assembly of the ITA, Oslo

The conference theme is Challenges for the 21st century, including: tunnelling & the environment, hydro schemes and caverns for public use. Venue: Radisson SAS Plaza Hotel. **Contact: PLUS. Tel +47 22 83 11 28. Fax +35.**

June 7-10 Geotechnical engineering for transportation infrastructure, Amsterdam

This XIth European conference on soil mechanics and foundation engineering will be held in Amsterdam, The Netherlands, under the auspices of the International Society for Soil Mechanics & Foundation Engineering. Session subjects include: General aspects of transportation infrastructure; High-speed railways and subways; Developments in the design & construction of tunnels. **Contact: XIth ECSMFE 1999. Tel: +31 30 2354064. Fax: +31 30 2357229.**

June 9-15 GEOSPECTRA 99, Dusseldorf

This international trade fair for Geotechnology and Applied Earth Sciences will take place at the Dusseldorf Trade Fair Centre and is part of Technology Forum International. Focus areas of GEOSPECTRA include: soil & foundation technology; geological IT systems; and digital image processing, simulation and visualisation. **Contact: Petra Hartman, GEOSPECTRA. Tel: +49 211 4560-991. Fax: +49 211 4560-548.**

June 21-23 Rapid excavation & tunnelling conference, Orlando

To take place at the Renaissance Hotel in Orlando, Florida, the RETC is a combined conference and exhibition and a major North American tunnelling event. This 14th international conference will examine current projects, technologies and innovations. **Contact: Exhibits Coordinator, RETC, Society for Mining & Metallurgy, PO Box 625002, Littlejohn, CO 80162-5002. Tel: + 1 303 973 9550. Fax: +1 303 979 3461; e-mail: roe@smenet.org.**

July 19-21 Geotechnical aspects of underground construction in soft ground, Tokyo

The ISSMGE technical committee TC28: Underground Construction in Soft Ground is holding its international symposium at the Tokyo Exhibition Centre concurrently with the 50th anniversary of the Japanese Geotechnical Society. **Contact: Prof. K Fujita, Science University of Tokyo. Fax: +81 471 23 9766.**

September 8-10 Tunnel Construction & Piling 99

This event, to be held at London's Olympia II, is the successor to Tunnelling 97. The international exhibition will cover plant, equipment, ancillary services for the design, construction, maintenance and refurbishment of tunnels worldwide. The associated symposium is supported by the Institution of Mining & Metallurgy, the British Tunnelling Society and the Federation of Piling Specialists. **For the exhibition, contact: Victoria Telfer at Brintex. Tel: +44 171 973 6663. Fax: +44 171 233 5054. For the symposium, contact: Laura McGowan at Brintex. Tel: +44 171 973 6643. Fax: +44 171 973 6600.**

September 27-30 8th international underground space conference

To be held at Xian University of Architecture and Technology, Xian, China. Sponsors are: the Associated Research Center for Urban Underground Space (ACUUS). The theme will be the preservation of the environment by further developing underground space. There will be an accompanying exhibition. **Contact Hou Jiyao at the School of architecture at the university. Tel: +86 29 7212647. Fax: +86 29 7212513.**

October 11-13 17th International No-Dig 99

To be held at HUNGEXPO in Budapest, Hungary. The general theme will be: Central Europe - the market for trenchless technology. There will also be an extensive exhibition. **Contact: Christiane Vortisch at Hamburg Messe und Congress. Tel: +49 40 3569 2248/2244. Fax: +49 40 3569 2269.**

October 25-28 Underground Works - ambitions and realities

The French Tunnelling Society's (AFTES) international conference will be held at the Congress Centre of the Cité des Silences et de l'Industrie in Paris. Themes include: Recent developments in architecture, design and non-destructive surveying of underground structures; Advances in construction techniques; Quality assurance, control and standardisation; Technical and financial organisation; Contractual and risk management. **Contact: AFTES. Tel: +33 1 53 42 94 69. Fax: +33 1 53 42 08 20**

November 11-12 T&T's tunnelling symposium '99, Beijing

Contact Werner Jazdziewski. Tel: +44 1732 377148. Fax: + 377219

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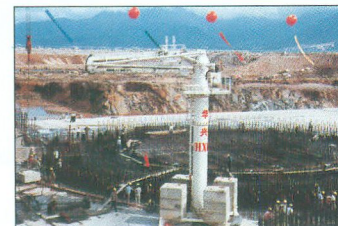
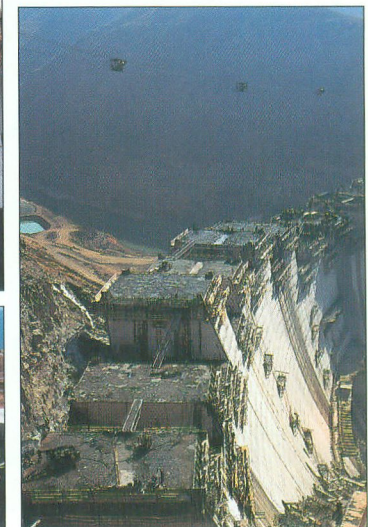
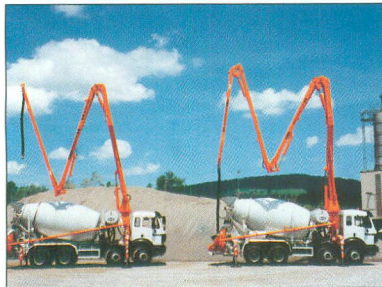
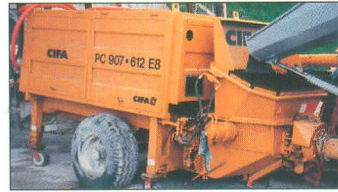
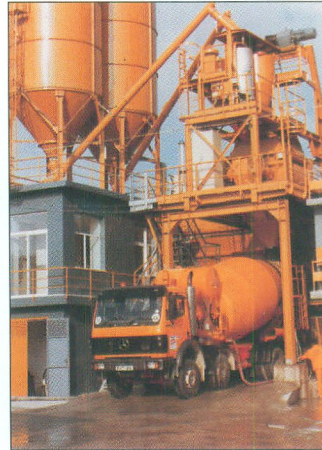
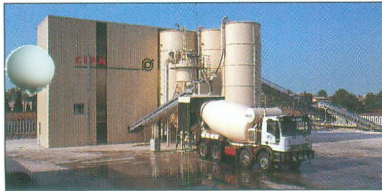
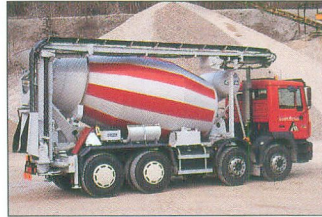
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