In December 2005, Dragages Hong Kong Limited (Dragages) was awarded a contract by CLP Power Hong Kong Limited (CLP) to design and construct the 4.5km Castle Peak Cable Tunnel and other associated works. The 4.5m-diameter tunnel was constructed using a Tunnel Boring Machine (TBM). Upon completion of the electrical and mechanical works, the tunnel will house CLP’s high-voltage cables running from Black Point and Castle Peak Power Stations to Tuen Mun, ensuring a reliable supply of power to Tuen Mun District, Hong Kong International Airport and Tung Chung. This case study presents in brief the ways Dragages overcame various constraints and challenges, setting a new standard for tunnelling works in Hong Kong.
The scope of works included design and construction of both civil and electrical and mechanical works for the Castle Peak Cable Tunnel, as well as associated works, such as the construction of portal and shaft buildings, cable troughs and a recreational playground. The 4.5m internal diameter tunnel spans 4.5km between Lung Fai Street, adjacent to Castle Peak Power Station, and Tuen Mun Wu Shan Playground, adjacent to Sun Tuen Mun Centre. A permanent portal / shaft structure is located at each end of the tunnel.
Sophisticated project involves various technical challenges

The two works areas were located at each end of the tunnel. Existing underground utilities included a natural gas main supplying fuel to Castle Peak Power Station and CLP high-voltage cables supplying electricity to the city. These two existing utilities, crossing the TBM launch box, were of utmost importance and could not be disrupted or diverted during construction. In particular, very stringent requirements regarding vibration (alert level 7mm/s) and settlement (alert level 10mm) were imposed for the gas main. Meanwhile, the works area in Tuen Mun was located in close proximity to Sun Tuen Mun Centre (STMC), a residential complex of more than 3,000 apartments.

The geological risks for this tunnel included uncertain ground conditions; six faults were predicted along the tunnel and a section of about 300m at the Tuen Mun end was in a low rock head covered situation with a majority of Completely Decomposed Volcanic (CDV) materials. In addition, the Tuen Mun end was located adjacent to many public utilities and structures such as gas mains, water mains, power cables, a box culvert, Light Rail tracks, highways, and a footbridge.

The Pillar Point Valley Landfill is also situated about 200m away from the tunnel alignment at its closest point. This posed the risk of landfill gas infiltrating the tunnel, although the possibility was low according to a Landfill Gas Hazard Assessment Report.

Meticulous planning ensures design optimisation

After taking into account the project’s geological risks, safety requirements and work environment, Dragages chose to use a double-shield hard rock TBM manufactured by HERRENKNECHT. The TBM was equipped with a 360-degree probe-drilling and grouting machine to cope with the geological faults and potential water ingress. Dragages also introduced a Refuge Chamber on the TBM, which is the first time such a facility has been used in Hong Kong. The Refuge Chamber was capable of holding up to 16 people for 12 hours in an emergency.

Design optimisation and value engineering were an on-going process in the project. Optimisation in the permanent works design such as the CLP cable jointing bays, niches, shaft and portal structures were achieved, greatly enhancing the overall work efficiency of the project. The temporary works design at the Castle Peak Works Area was also optimised to allow TBM launching as early as possible, which included the use of precast elements for the site set up such as a TBM launch box, aggregate and tunnel spoil storage basins and adjusting the chainage of TBM break-in. In view of the risks associated with low rock cover and the CDV ground at the Tuen Mun end, the vertical alignment of the tunnel was lowered and the depth of the Tuen Mun Shaft was increased by about 12m.
Record-breaking TBM excavation works

The main technical difficulties encountered in TBM excavation included:
- unexpected rock hardness and unfavourable rock jointing
- unexpected water inflow in the quartzite zone
- crossing of wide and weak fault zones with large water inflows

Despite various technical challenges, Dragages managed to achieve excellent TBM progress, even breaking the record for monthly production in Hong Kong. On average, tunnel construction proceeded at 410 metres per month, with the best month achieving 703.5 metres.

TBM break-in took place at the Castle Peak side in November 2007. An innovative break-in method with a sliding thrust frame was used which required no temporary rings or cavern for the TBM launching. A Construction Noise Permit (CNP) for round-the-clock TBM operations was obtained from the Environmental Protection Department (EPD) and two shifts of 10 hours plus 4 hours maintenance was implemented.

Rock hardness was an issue during TBM excavation, resulting in a high level of TBM wear and tear. However, with regular inspection and professional maintenance works, machine breakdowns were minimised. Advance probe drilling and grouting works were also undertaken at faults, in particular at the major fault located in Tuen Mun where more than 120,000 litres of grout was applied. Additional measures were taken to dispel concerns of ground and utilities settlements when the TBM excavation reached the Tuen Mun end. These measures included close monitoring of the TBM parameters while digging as well as the conditions at the ground surface, applying the right quantity of grout from the TBM before advancing, and maintaining the good functioning of all recharge wells.
TBM break-out at the Tuen Mun Shaft took place in October 2008. Due to the absence of a blasting permit, shaft rock excavation could not be completed for TBM arrival. In order to minimise the overall impact to the entire project, Dragages employed an alternative TBM break-out method by extending the excavation of the tunnel within the shaft zone using the TBM. This created a temporary TBM parking cavern, which enabled the smooth completion of shaft excavation.

Innovative solutions ensure minimal disruption to the community

Dragages successfully obtained a CNP from the EPD to allow hole-drilling from 19:00 to 23:00 hours. A special noise cover, able to reduce the noise level by 24 dB(A), was also used to cover the shaft while carrying out rock excavation works. The rock excavation was completed in January 2009. The impact of the delay in rock excavation was minimised by undertaking mitigation measures such as fast-tracking the shaft structure works, and rearranging the electrical and mechanical works.

Green concerns prompt innovative safety and environmental management

At every stage of project planning and implementation, Dragages took great care to identify measures required to mitigate safety and environmental risks. Through effective planning and efficient site installations, most concerns on safety and environmental aspects were addressed before works commenced.

Environmentally-friendly and safety measures included:

- Design of the TBM with ergonomic principles in mind.
- To deal with the potential infiltration of landfill gas, a comprehensive set of control systems were also put in place, including the provision of a Refuge Chamber
- Use of pre-cast concrete wherever possible. In total, more than 95% of the permanent structures and temporary installations were pre-cast off-site
- Recycling of waste water throughout the project on tunnelling works. Indeed, 70% of the total water used on site came from recycled sources
- Use of a noise cover at the Tuen Mun Shaft, which reduced the noise level by 24 dB(A)
- Reuse of top soil and tunnel spoil on other projects
- Converting of felled trees to compost and mulch

 Shaft noise cover in Tuen Mun works area

Application of compost
Castle Peak Cable Tunnel

Quick Facts
- 4.5km-long tunnel, CLP’s longest tunnel
- 4.5m-diameter, CLP’s largest tunnel
- 120-year life span
- Project completed in 2.5 years

About the Tunnel Boring Machine
- Double-shield
- Average monthly production: 410 metres
- Record-breaking monthly production in Hong Kong: 703.5 metres
- 1st Refuge Chamber to be used on a tunnel project in Hong Kong

Sustainability
- Adoption of pre-cast elements for more than 95% of structures
- Recycled water accounted for more than 70% of the total water consumption
- 90m³ of topsoil was recycled for a tree nursery
- 21,400 tonnes of tunnel spoil were recycled for neighbouring construction works
- Felled trees were recycled
- Noise levels were reduced by 24dB(A) through the adoption of a noise cover during the shaft construction phase

Award-winning success
Dragages’ commitment to partnership with the community and environmental management was recognised with various awards:

Construction Industry Safety Award Scheme
Co-organised by 13 organisations such as the Labour Department, Occupational Safety & Health Council, and the Development Bureau:

2008/2009
- Civil Engineering Sites Category – Gold Award
- Safety Teams – Meritorious Award
- Subcontractors – Gold Award

2007/2008
- Civil Engineering Sites Category – Bronze Award
- Safety Teams – Silver Award

Good Housekeeping Award
Organised by the Occupational Safety & Health Council:

2008/2009
- Bronze Award

Considerate Contractors Site Award Scheme
Organised by the Development Bureau:

2008
- Outstanding Environmental Management & Performance – Gold Award
- Considerate Contractors Site Award (Non-Public Works - New Works) – Bronze Award

2007
- Outstanding Environmental Management & Performance – Silver Award
- Considerate Contractors Site Award – Bronze Award