The Construction of Recent Tunnels in Hong Kong

Introduction

The construction of tunnels is seldom notice by the public. There are practical reasons for this; the location of tunnels is often very remote and most tunnel works are carried out below ground and generally out of sight. Many and varied risks occur during the tunneling process, such that clients or contractors usually act in an extremely low-profile attitude and requests to visit the working sites by most outsiders are normally not entertained.

In the recent years, due to heavy investment by the government in the development of infrastructure in Hong Kong, a great number of tunnels are being built, with a few still under construction. Hong Kong has been one of the most active places worldwide for tunneling works. The following table summarizes some of the major recent tunnel projects in Hong Kong.

The construction of tunnels in Hong Kong faces some unfavourable factors, such as:
a) Hong Kong's geological conditions consist of very hard rock that makes excavation very difficult and time consuming.
b) Working spaces required for work depots, tunnel portal, assembly of tunneling equipments, temporary storage and the fabrication of tunnel segments or immersed tubes are very limited.
c) Encountering congested underground services is common, and re-alignment or diversion works are often required in conjunction with the tunneling works.
d) Similarly, complicated traffic diversions are often required especially where works are within urban sites.
e) Noise, waste, air and dust nuisances created during the work process are subject to stringent environmental by-laws.
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In general, the solutions are often unrelated to technology, they are a matter of cost. Constructing tunnels in Hong Kong is therefore, unavoidably, quite expensive.

On the technology aspects, there are a number of effective ways to construct tunnels of various types in Hong Kong. These include:

a) Cut and cover method - suitable for use in relatively softer ground with a tunnel running not too deep from the ground surface. Example: most of Airport Railway tunnel sections within metro areas.

b) Drill and blast method - suitable for use in tunnels with very large cross sections and running through hard rock areas. Examples: most major tunnels in Hong Kong including Tate's Cairn Tunnel and Route 3 Tai Lam Tunnel.

c) Employing a tunnel boring machine - basically can be used in any type of geological environment depending on what type of machine is selected, preferably to be used in tunnels with smaller cross section and with reasonable length in order to make the extra works for assembling and dismantling of the machine more cost effective. Example: KCRC West Rail Kwai Tsing Tunnel.

d) Immersed tube method - suitable for constructing underwater tunnels. Examples: All the three cross-harbour tunnels in Hong Kong.

e) No trench method - suitable for constructing short tunnels within urban environment. Example: pedestrian subway linking MTR Central Station to Hong Kong Station. (Please also refer to "15 Most Outstanding Projects in Hong Kong" written by the author in 1998)
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The choice of method to construct a tunnel depends highly on several critical factors, which include:

a) Geological conditions - affecting both the type of machines, construction methods and technical standards to be employed.
b) Length of tunnel - determining the effectiveness of using appropriate equipment, such as the use of a tunnel boring machine, or a particular type of spoil disposal system.
c) Location of tunnel.
d) Availability of working spaces.
e) Construction planning and time schedule.
f) Contract procurement methods.
g) Environmental requirements.

Tunneling is highly specific work in the civil engineering disciplines. This article is therefore not intended to provide a detailed report or analysis of tunnel technology. The author just wishes to make use of some of the representing projects in Hong Kong as shown in the photo essay, to give a general summary by using recent examples of how tunnels of various types can be constructed.
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## Introduction

<table>
<thead>
<tr>
<th>Name of Tunnel</th>
<th>Year* of Construction</th>
<th>Client/Contractor</th>
<th>Approx. Cost</th>
<th>General Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tseng Kwan O Tunnel</td>
<td>1987 – 1989</td>
<td>Highways Department/</td>
<td>N/A</td>
<td>- 800m long.</td>
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<td></td>
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<td>- 2 lanes/2 ways traffic</td>
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<td></td>
<td>- construction: drill and blast.</td>
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<tr>
<td>Shing Mun Tunnels</td>
<td>1986 - 1989</td>
<td>Highways Departments/ Dragages et Travaux Publics</td>
<td>N/A</td>
<td>- 2.2km in 2 separate tunnel sections.</td>
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<td></td>
<td></td>
<td></td>
<td>- 2 lanes/2 ways traffic</td>
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<td></td>
<td></td>
<td></td>
<td>- construction: drill and blast.</td>
</tr>
<tr>
<td>Tate's Cairn Tunnel</td>
<td>1989 - 1991</td>
<td>Nishimatsu-Gammon led Consortium/ Nishimatsu-Gammon JV</td>
<td>$2.1 billion</td>
<td>- 3.6km long.</td>
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<td>- 2 lanes/2 ways traffic</td>
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<td></td>
<td></td>
<td>- construction: drill and blast.</td>
</tr>
<tr>
<td>Cheung Tsing Tunnel, Route 3</td>
<td>1994 - 1996</td>
<td>Highways Department/ Dragages et Travaux Publics</td>
<td>$0.85 billion</td>
<td>- 1.5km long.</td>
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<td></td>
<td>- 3 lanes/2 ways traffic</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>- construction: drill and blast.</td>
</tr>
<tr>
<td>Tai Lam Tunnel, Route 3</td>
<td>1995 - 1997</td>
<td>Route 3 (Country Park Section) Co. (Franchisee)/ Route 3 Contractor's Consortium consisting Nishimatsu, Dragages and Gammon</td>
<td>$7.25 billion including the entire Route 3 (CP Section), tunnel work about $2.5 billion</td>
<td>- 3.7km long, overall measures 15.5m x 10.5m high for each main tube.</td>
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<tr>
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<td>- 3 lanes/2 ways traffic</td>
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<td></td>
<td></td>
<td>- construction: drill and blast.</td>
</tr>
</tbody>
</table>
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<table>
<thead>
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<tbody>
<tr>
<td><strong>Kamaghai led Consortium/Nishimatsu-Gammon JV</strong></td>
<td><strong>Western Harbour Tunnel Co. Ltd. / Nishimatsu-Kumagai JV</strong></td>
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<tr>
<td>$4.2 billion</td>
<td>$5.7 billion</td>
<td></td>
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<tr>
<td><strong>2.3km long, submerged twin-tube tunnel with rail and 2 lanes/2 ways traffic.</strong></td>
<td><strong>1.25km, 3 lanes/2 ways traffic</strong></td>
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<td><strong>construction: immersed tubes.</strong></td>
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<table>
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<tr>
<th>Railway Tunnels</th>
<th>Description</th>
<th>Cost</th>
<th>Details</th>
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<tbody>
<tr>
<td>Tunnel for Airport Railway linking Tsing Yi Station to Tsing Ma Bridge</td>
<td>1995 - 1996</td>
<td>MTRC/Downer-Zublin JV</td>
<td>$0.45 billion including 600m section of viaduct</td>
</tr>
<tr>
<td>Tunnel for Quarry Bay Congestion Relief Scheme, MTRC</td>
<td>1997 - 1999</td>
<td>MTRC/Nishimatsu</td>
<td>$1.2 billion</td>
</tr>
<tr>
<td>Tai Lam Tunnel, KCR West Rail</td>
<td>1999 - 2001</td>
<td>KCRC/Nishimatsu-Dragages JV</td>
<td>$1.8 billion</td>
</tr>
<tr>
<td>Kwai Tsing Tunnel, KCR West Rail</td>
<td>1999 - 2001</td>
<td>KCRC/Dragages-Zen Pacific JV</td>
<td>$1.9 billion</td>
</tr>
<tr>
<td>Black Hill Tunnel linking Yau Tong to Tiu Keng Leng, MTR Tseung Kwan O Extension</td>
<td>1999 - 2000</td>
<td>MTRC/DUMEZ-GTM-Chun Wo JV</td>
<td>$1.6 billion</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Services Tunnels</th>
<th>Start Date</th>
<th>Contractor 1</th>
<th>Contractor 2</th>
<th>Total Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Tunnel in Hong Kong Island</td>
<td>1990 - 1992</td>
<td>Hong Kong Electric/ Nishimatsu</td>
<td>N/A</td>
<td>5.5km long, 3.5m diameter</td>
<td>construction: tunnel boring machine.</td>
</tr>
<tr>
<td>Tunnel linking Butterfly Valley and Tai Po for Water Treatment and Transfer Scheme</td>
<td>1998 - 1999</td>
<td>Water Supplies Department/ Kumagai-Leighton JV</td>
<td>$1.1 billion</td>
<td>12km long, 3.8m diameter</td>
<td>construction: tunnel boring machine.</td>
</tr>
<tr>
<td>Waste Water Disposal Tunnels for the Strategic Sewage Disposal Scheme (SSDS)</td>
<td>1996 - 2001 (?)</td>
<td>Drainage Services Department/ Paul Y-SELI JV, Gammon-Kvaerner JV and Skanska</td>
<td>Total $8.2 billion ($1.7 billion for tunnel works, 1997 price)</td>
<td>Total 23.5km long in 6 major tunnels under 3 separate contracts, tunnel diameter ranging from 1.5m to 2.6m (excluding lining) and with depth ranging from -87mPD to 142mPD</td>
<td>construction: tunnel boring machine.</td>
</tr>
</tbody>
</table>

* period for major civil works only
The entrance arrangement to the tunnel portal for the 3.7km long Tai Lam Tunnel of Route 3 at Kam Tin as seen in early 1996. Tai Lam Tunnel consists two main tunnels, each measures 15.5m wide and 10.5m high, and a 950m long servicing duct for ventilation and other supply purposes in between the main tunnels.
The erection of the gantry-type formwork for the forming of tunnel lining at the entrance of the tunnel portal on Ting Kau side.
A trial section of tunnel excavation making use of New Austrian Tunnel Method.
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Tai Lam Tunnel -- Route 3, Country Park Section

Explanation drawing showing the excavation sequences using the New Austrian Tunnel Method. The principle of using this method to construct a large-scale tunnel is to sub-divide the tunnel section into several arched smaller sections for easier control and more effective support during excavation. The newly formed surfaces often require temporary support by girder sections, shotcrete, nails or anchors.
After the tunnel formed by a drill and blast process, the newly formed tunnel surface is lined with an in-situ concrete lining to stabilize the exposed soil or rock faces. The photo shows the gantry-type formwork used to construct the in-situ concrete lining.
Interior of the Tai Lam Tunnel before paving. Also taking place is the installation of the service void using a precast ceiling panel.
The machine, known as the Jumbo tunneling machine, is used to drill and form holes inside the tunnel for the placing of explosive to activate the blasting. The Jumbo machine is computer-controlled and is capable of drilling three holes at the same time with direction or angle set precisely.
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Tunnel linking Butterfly Valley and Tai Po

The tunnel boring machine used for the formation of the tunnel tube on the Butterfly Valley side with a diameter of 3.8m.
Close up of the cutter head. The cutting disc can cut into hard rock and the granulated spoils will be collected and removed by a conveyor system that is positioned immediately rear of the cutting head.
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Tunnel linking Butterfly Valley and Tai Po

Soil disposal wagons at the disposal area on Butterfly Valley side portal. The spoil will be kept at this location prior to removal off-site by dumping vehicles.
Arrangement of the portal as viewed from the tunnel exit. The spoil disposal area is located on the right side of the exit with rail tracks heading in that direction. The rail tracks on the left lead to the depot and servicing centre for the soil disposal wagons, as well as for general loading and unloading purposes.
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Tunnel linking Butterfly Valley and Tai Po

A view of the tunnel interior with the partly formed lining, tunnel supporting girders, rail track for soil disposing wagon, ventilation hose and other supply pipe lines.
A similar tunnel-boring machine employed for the forming of a cable tunnel for the Hong Kong Electric on the Hong Kong Island side. Observe the hydraulic jack systems behind the cutter head that enable the machine to stabilize itself, push forward, or even slightly adjust its direction.
The formation of the tunnel portal for the Kwai Tsing Tunnel on the Mei Foo side.
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**Kwai Tsing Tunnel -- KCR West Rail**

The tunnel portal gradually in shape.
The tunnel portal during the process of tunnel excavation can serve several purposes: to provide an entrance into the tunnel tube to facilitate the movement of tunneling equipment and materials; as an exit for the disposal of spoils; to form a ramp into the tunnel tube which is usually at sub-grade level; or to provide supporting space for the temporary storing or assembly of equipment.

This photo shows a traveling-type working gantry under assembly inside the portal area of Kwai Tsing Tunnel at Mei Foo side.
The completion of the 25 m wide tunnel entrance, cutting across about 10m above which is the Lai King Hill Road. The formation of such a large void below a roadway can seriously endanger the stability of the road sub-structure. Note the waling and rock anchors above the entrance and the rib-form structure, a type of lattice girder beam, which helps to support Lai King Hill Road.
The Jumbo tunneling machine at work in the formation of the tunnel entrance.
Typical tunnel sections showing the routing and formation of Kwai Tsing Tunnels from Mei Foo to Tsuen Wan.
An access and servicing shaft located at Lai King at the mid-way of the Kwai Tsing Tunnels. The traditional drill and blast method is used to construct the tunnels from Mei Foo to the shaft here at Lai King. The section further on heading towards Tsuen Wan uses a mixed-ground earth pressure balanced tunneling machine (EPBM).
The general layout arrangement of the work depot and tunnel shaft located at Tsuen Wan near Water Side Plaza. Besides serving as the tunnel portal, this shaft is also used for the assembly of the EPBM for the forming of the Kwai Tsing Tunnels from Tsuen Wan to Lai King.
Sections of the shield of the EPBM before assembly and the precast segments for the forming of the tunnel lining in storage at the work depot in Tsuen Wan.
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Kwai Tsing Tunnel -- KCR West Rail

The shield of the EPBM being lowered into the shaft for onward assembly. The 8.7m diameter cutter head will later be connected to the front (on the left side) of the shield.
The working principle of the mixed-ground earth pressure balanced tunneling machine under the open mode and earth pressure balanced mode.
The trial assembly of the EPBM at the fabricating factory at Shanghai prior to shipment to Hong Kong.
Lowering the cutter head of the EPBM into the tunnel shaft.
The cutter head is being connected to the shield of the EPBM by the help of a track-mounted gantry crane positioned on the ground level. The rows of steel tubes on the background provide lateral support used to stabilize the 25 m deep tunnel shaft.
The overall view of the EPBM pictured at the machine's commissioning ceremony on 31st March 2000.
View of portal of Tai Lam Tunnel at Chai Wan Kok in the direction towards the Tuen Mun Highway. The elevated bridges in the far background are the main connecting bridges at the entrance to Tuen Mun Highway. Since the tunnel will cut through the foundation of one of the elevated bridges, underpinning work for the foundation is required before proceeding with actual tunnel excavation.
A servicing gantry unit under assembly. This unit is mounted with ventilation fans and its function is to provide fresh air and air circulation inside the tunnel.
The ventilation gantry unit at work inside the tunnel. Note the I-section girders which act as temporary support to the exposed face of the tunnel before the forming of permanent lining using in-situ concrete.
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Tai Lam Tunnel -- KCR West Rail

The portal arrangement of Tai Lam Tunnel at Kam Tin side.
The gantry type scaffold used to install the waterproofing membrane. The majority of servicing equipments used inside tunnels are mounted on tracks and constructed in gantry form shaped to fit the section of the tunnel interior.
An overall view of the tunnel lining formwork gantry used to construct the in-situ concrete lining of the tunnel.
The tunnel interior with the in-situ concrete lining already in place.
An aerial view showing the overall layout of the Hong Kong Station and the approach tunnels for the Airport Railway (Airport Express Line and Tung Chung Line) at the Central Reclamation in late-1996.
A 400m section of approach tunnels connecting Hong Kong Station and the immersed tube harbour crossing tunnel formed using the cut-and-cover method. This method is more effective and economical to construct shallowly positioned tunnel in softer ground (reclaimed land in this case, with limited marine boulders). Diaphragm wall strutted with steel tube and soldier piles wall supported by ground anchors are both used to form the cut-off systems during the excavation of the tunnels.
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Cut and Cover Tunnel for the Airport Railway at the Central Reclamation

The approach tunnels taking in shape. The portion on the left hand side of the temporary pedestrian bridge is the ground structure of the Hong Kong Station. The structure on the right end of the tunnel near the seawall houses the flood gate and other control and electrical gears for the tunnel system. From that section onward, the tunnel crosses the Victoria Harbour through the immerse-tube tunnel.
Section of the tunnel pit formed by diaphragm wall and strutted by the use of steel tubes. The construction of the tunnel sections using in-situ method can be seen inside the pit.
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Cut and Cover Tunnel for the Airport Railway at the Central Reclamation

Section of the tunnel pit formed by soldier pile wall and laterally supported by anchors. The structure of the approach tunnel has basically been completed pending for backfilling at a later stage.
Western Harbour Crossing is constructed using precast concrete immersed tube sections. A total of 12 sections were used, each measuring 113m x 33.5m x 8.5m high and weighing about 35,000 tons. This photo shows one of the three batches of immersed tubes being formed in the casting yard at Shek O, Hong Kong.
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Western Harbour Crossing

The arrangement of the approach tunnels on West Kowloon Reclamation side. As can be seen here, the ventilation building also serves as the coupling structure to receive the first approaching immersed tube. After the tube is connected, the water embraced by the elbowing land is filled to secure the coupling connection and make the tube land-bound.
The second immersed tube being towed to the launching position for sinking and connecting onto the first tube. The first tube at this stage has already been firmly positioned at the seabed and cannot be seen on the surface.
Touching up of the land surface after the completion of the immersed tube connection. Note also the construction of the tunnels for the Airport Railway on the right hand side of the reclaimed land.