Tunnel Construction - Recent Projects in Hong Kong

The construction of tunnels is often quite un-notice to general public. There are practical reasons for this, such as, the location of tunnels is often very remote; most of the tunnel works are carried out below surface of ground and generally beyond vision of public eyes; various forms of risks may occur during the tunneling processes that client or contractor of tunnel projects usually act in an extremely low-profile attitude; the operation of tunneling works are highly dangerous that request 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 within the territory of Hong Kong, a great number of tunnels are being built, with a few of which are still under construction. Hong Kong has been one of the very active places on earth for tunneling works. The appended table summarized some of the major tunnel projects in recent Hong Kong.

Construction of tunnels in the environment of Hong Kong does impose some unfavourable factors, such as:

- Geological conditions of Hong Kong consists of very hard rock that makes excavation very difficult and time consuming.
- Working spaces that are required for the provision of work depots, tunnel portal, assembly of tunneling equipments, temporary storages, fabrication of tunnel segments or immersed tubes etc., are very limited.
- Encountering of congested underground services is common that re-alignment or diversion works are often required at the same time with the tunneling works.
- Similarly, complicated traffic diversions are often required especially where works within urban sites.
- Noise, waste, air and dust nuisances created during the processes of work are subject to stringent environmental by-laws.

In general, the solution is often un-related to technology, it is a matter of cost. Constructing tunnels in Hong Kong are therefore unavoidably quite expensive. Besides, tunnel often requires very large land area to accommodate an approach section and other traffic connections leading to the entrance of the tunnel. This makes the use of tunnel as a relief to traffic in particular in congested built area in Hong Kong not very possible.

However, the option to use tunnel still poses several advantages:

- During the construction of the tunnel fewer disturbances will be created due to majority of works are carried out in a concealed manner under ground.
b) It provides a more environmentally friendly mode of transportation for underground tunnel can confine the spread of noise and other air-bourn pollutants to the atmosphere.

c) Tunnel can free the land above it for other purposes.

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

a) Cut and cover method
   - Suitable for use in relatively softer ground with tunnel running not too deep from the ground surface.
   - The cost of construction of relatively lower.
   - Sequence of construction:
     ~ provide cut-off structure as side support during excavation
     ~ start excavation to form the tunnel trench as exposed sides further supported by strut or other lateral support systems
     ~ construct the tunnel section at the formation level of trench using in-situ methods (formwork, reinforcement fixing and place concrete)
     ~ repeat the process of excavation and tunnel construction section by section until the full length of tunnel is completed
     ~ backfill the excavated trench and re-instate the ground surface
   - Examples: most of the tunnel sections of Airport Railway within metro areas; MTR Tseung Kwan O Line; West Rail tunnel between Nam Chong and Mei Foo Stations

b) Drill and blast method
   - Suitable for use in tunnel with very large cross section area and running through hard rock areas or runs deep in the ground.
   - Sequence of construction:
     ~ carry out thorough soil investigation to ensure the geotechnical condition along the entire alignment of the tunnel
     ~ set up a work depot/portal usually at the entrance of the tunnel to support the construction before the carrying out of the drill and blast works (facilities in the depot include: equipment assembly and maintenance point, material storage areas, spoil handling facilities, fresh air supply system or other safety/logistic support etc.)
carry out a trial drilling process to get familiar with the operation and
to obtain the necessary work data for work in full scale at a later stage.

forming the tunnel using drill and blast: drill the holes (averaged 5 to
8m deep) within the tunnel section using drilling machines for the placing
of explosive charges, the blast will loosen the rock and make excavation
possible afterward

remove the excavated spoil by conveyor belt or dumping vehicles
from the drilling point.

stabilize the freshly excavated tunnel section by waling, rock anchor
or rock nail where necessary

form the tunnel lining (usual concrete) as the permanent support to
the tunnel interior

form the road surface, install related services (lighting, power supply,
ventilation, signaling) and final finish the tunnel

Examples: most major tunnels in Hong Kong including Tate’s Cairn
Tunnel, Tai Lam Tunnel of Route 3 and the major tunnels of Route 8.

c) Employing Tunnel boring machine

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.

Sequence of construction:

similar to the early stage arrangement using drill and blast method

tunnel portal of sufficient size is to be provided to facilitate the
assembly and handling of the tunnel boring machine

carry out trial-run of the TBM to get familiar of the system

start using the TMB to do the excavation in full scale

after completion of the tunnel drilling, finish the tunnel similar as the
drill and blast method

dismantle the TBM after completion of all drilling works

Other features of the tunnel boring machine:

TBM consists of a) drilling head, b) hydraulic driving system to
station the machine during the drilling and to push it advance when a
section of drilling is completed, c) spoil removal mechanism usually in the
form of conveyor, and d) power generating unit for the machine is mainly electrical operated

~ tunnel so formed by TBM is in circular section, usual ranging in size from 1.5m to 9m diameter.

~ TBM usually equipped with the tunnel lining installation mechanism (tunnel lining usually in the form of precast unit)

- Example: KCR Kwai Tsing Tunnel of West Rail, tunnel of KCR Lok Ma Chau Spur Line

d) Immersed tube method
- Suitable for constructing underwater tunnel only such as for all the three cross harbour tunnels in Hong Kong.
- Immersed tube can be constructed in steel or in precast unit
- Very complicated to construct in particular forming the connection on the land-side tunnel section at two ends.
- Large working area is required in particular the prefabrication yard to form the immersed tubes
- Sequence of construction:
  ~ construct the immersed tube sections usually in a dry dock to allow the completed sections to transport to the harbour location for installation
  ~ form the base trench on the sea-bed by dredging for the placing of the immersed tunnel tubes afterward
  ~ form the tunnel approach (access ramp) on the land-side as entrance/exit to the future tunnel.
  ~ form the connection structure to connect the immersed tube (sea-side) to the tunnel approach (land-side), usually by the fill and re-excavate process

e) No trench method – suitable for constructing short tunnel within congested 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 Raymond Wong in 1998)

The choice of method employed to construct tunnels highly depends on a few critical factors, which include:

a) Geological conditions – affecting both the type of machines, construction method and technical standard to be employed.
b) Length of tunnel – determine the effectiveness of using appropriate equipments, such as the use of 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) The occurrence of possible risks (finance, management, engineering and construction aspects)

g) Contract procurement methods.

h) Environmental requirements.

Safety at work for tunneling

The construction of tunnel of any type is a very dangerous operation due to:

  a) Required to work underground, sometimes with the work position very deep down from the earth surface or far away from a safe exit.

  b) Sometimes work in very confined area (e.g. for traffic or service diversion works)

  c) Often required to work with a large number of heavy machines.

  d) Often required to handle dangerous goods (e.g. fuel oil or explosive) and large amount of bulky materials (excavation spoil)

  e) Confined space inside the tunnel is hazardous to health for workers (e.g. dust, toxic gases, noise and poor air quality)

  f) Soil or rock collapse often occurs during the excavation inside tunnel.

Epilogue

Tunneling is a highly expertise works in the civil engineering disciplines. This article is not intended to provide a detail report or analysis in 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 about how tunnels of various natures can be constructed.
<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/ Data not available</td>
<td>Data not available</td>
<td>800m long, 2 lanes/2 ways traffic; method of construction: drill and blast.</td>
</tr>
<tr>
<td>Shing Mun Tunnels</td>
<td>1986 – 1989</td>
<td>Highways Departments/ Dragages et Travaux Publics</td>
<td>Data not available</td>
<td>2.2km in 2 separate tunnel sections, 2 lanes/2 ways traffic; method of 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, 2 lanes/2 ways traffic; method of 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, 3 lanes/2 ways traffic; method of 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 &amp; Gammon</td>
<td>$7.25 billion for 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, 3 lanes/2 ways traffic; method of construction: drill and blast.</td>
</tr>
<tr>
<td>Eastern Harbour Crossing</td>
<td>1986 – 1989</td>
<td>Kamaghai led Consortium/ Nishimatsu-Gammon JV</td>
<td>$4.2 billion</td>
<td>2.3km long, submerged twin-tube tunnel with rail and 2 lanes/2 ways traffic.</td>
</tr>
<tr>
<td>Western Harbour Crossing</td>
<td>1993 – 1996</td>
<td>Western Harbour Tunnel Co. Ltd. / Nishimatsu-Kumagai JV</td>
<td>$5.7 billion</td>
<td>1.25km, 3 lanes/2 ways traffic; method of construction: immersed tubes.</td>
</tr>
<tr>
<td>Route 8 Nam Wan Tunnel</td>
<td>2003 - 2005</td>
<td>Gammon Skanska International Joint Venture</td>
<td>$1.5 billion</td>
<td>2.1km long twin-tube tunnel formed by drill and blast method.</td>
</tr>
<tr>
<td>Route 8 Eagle’s Nest Tunnel</td>
<td>2004 – 2005</td>
<td>Leighton - Kumagai Joint Venture</td>
<td>$1.8 billion</td>
<td>1.25km dual 3-lane tunnel formed by drill and blast method.</td>
</tr>
<tr>
<td>Railway Tunnels</td>
<td>Year</td>
<td>Contractor</td>
<td>Cost</td>
<td>Details</td>
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<td>----------------------------------------------------------------------------------------------------------</td>
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<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>
<td>1.4km, twin tunnels each of 6.5m diameter; method of construction: drill and blast.</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>
<td>2.2km long, twin tunnels each of 6.2m diameter; method of construction: tunnel boring machine.</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>
<td>5.5km long, single tube tunnel overall measures 13.8m x 9.1m high with partition wall in middle to form the north and south bound track; method of construction: drill and blast.</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>
<td>3.6km, twin tunnels each of 8.7m diameter; method of construction: drill and blast from Mei Foo to Lai King, tunnel boring machine from Lai King to Tsuen Wan.</td>
</tr>
<tr>
<td>Black Hill Tunnel linking Yau Tong to Tiu Keng Leng, MTR Tsuen Kwan O Extension</td>
<td>1999 –2000</td>
<td>MTRC/ DUMEZ-GTM-Chun Wo JV</td>
<td>$1.6 billion</td>
<td>1.7km long, twin tunnels each of 6.5m diameter, method of construction: drill and blast.</td>
</tr>
<tr>
<td>KCR Lok Ma Chau Spur Line, Tunnel from Sheung Shui to Chau Tau</td>
<td>2003 - 2005</td>
<td>Dragages (HK) Joint Venture</td>
<td>$2.8 billion</td>
<td>5.8km long, twin tunnels each of 8.5m diameter formed by tunnel boring machine (TBM)</td>
</tr>
<tr>
<td>Services Tunnels</td>
<td>Start – End</td>
<td>Contractor</td>
<td>Cost</td>
<td>Description</td>
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<td>--------------------------------------------------------------------------------</td>
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<tr>
<td>Cable Tunnel in Hong Kong Island</td>
<td>1990 – 1992</td>
<td>Hong Kong Electric/ Nishimatsu</td>
<td>Data not available</td>
<td>5.5km long, 3.5m diameter; method of 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; method of 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; method of construction: tunnel boring machine.</td>
</tr>
</tbody>
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* period for major civil works only