

Photo Illustration to support the teaching of the topic on Tunnel Construction

Prepared by Raymond Wong

Remember how to find a bore pile?

Three basic consideration:

- how to cut the soil/rock
- how to remove the spoil
- how to protect the bore hole from collapsing

Forming tunnel is similar to form a bore pile, but in a horizontal manner and in most cases in a much larger diameter.

Types of tunnel

How tunnel to be used:

- As passageway for vehicles or railway
- As passageway for the passing services such as cable or pipework
- For the passing of water like aquaduct
- For pedestrian underpassing

Tunnel can be formed within the following environment:

- Under water
- Along flat land or reclaimed land
- Entering into a hill
- Combination of the above environment

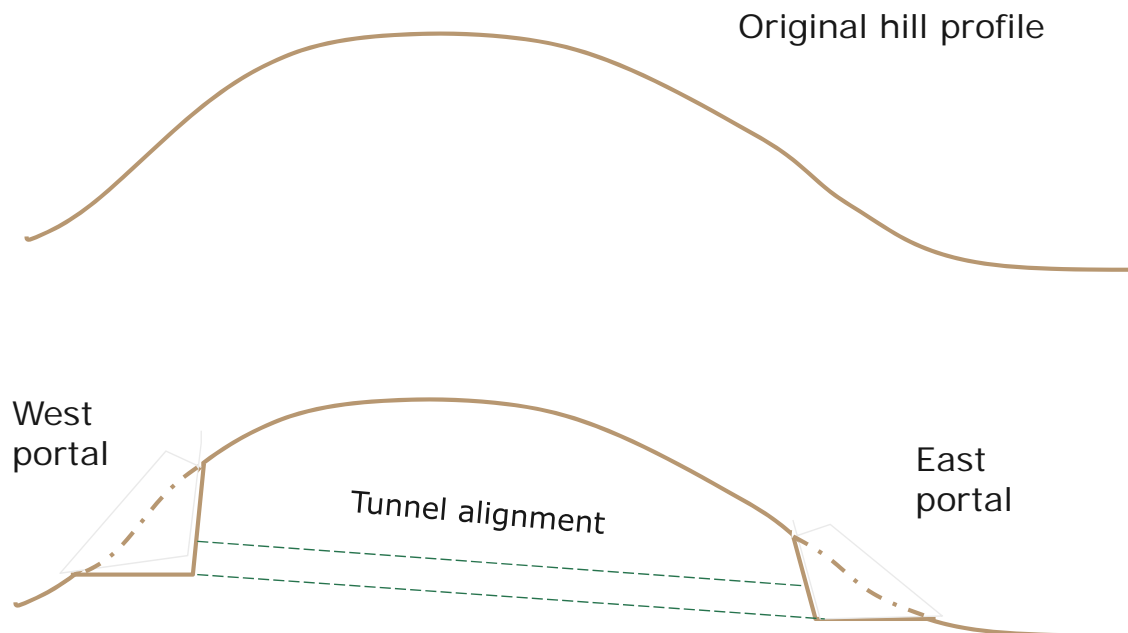
Tunnel Construction using Drill-and-Blast Method

Basic work involvement and principle of the method

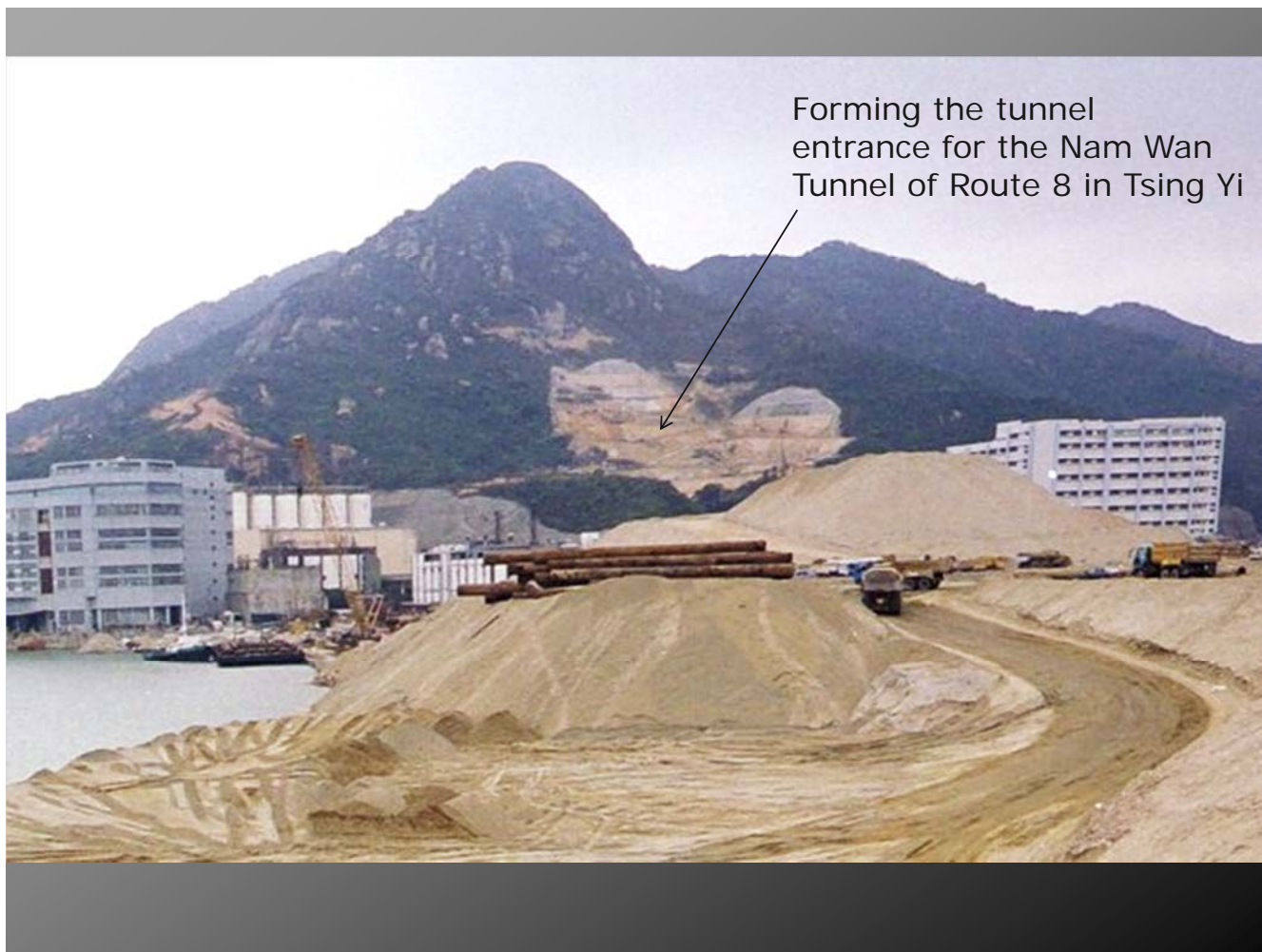
1. Site investigation to fully understand the geotechnical environment of the tunnel to be constructed.
2. Forming the entrance to the tunnel by necessary site formation.
3. Form a trial tunnel and fine-tune the tunnel alignment
4. Excavate the tunnel using drill and blast, section by section, each ranging from 3m to 5m depending on various design concerns
5. Remove the blasted rock by excavating machine and conveyor belt or dumping vehicles.
6. Temporary reinforce the newly cut tunnel section using shotcrete or truss members where required.
7. Form the tunnel lining using concrete (often with reinforcement)
8. Form the tunnel paving and other interior finishes/fitting.



A trial tunnel section being formed to start the tunnel cutting



Forming the tunnel portal (entrance) by site formation



Forming the tunnel entrance for the Nam Wan Tunnel of Route 8 in Tsing Yi



The entrance portal of tunnel at the early stage of site formation (above) and the completion of the final tunnel entrance

(Nam Wan Tunnel of Route 8 on Tsing Yi Island west)





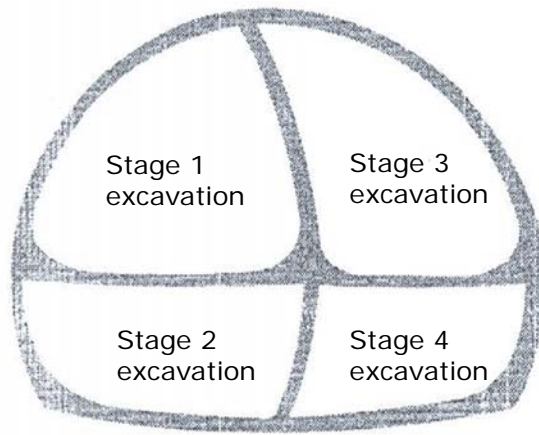
Entrance arrangement to the tunnel portal for the 3.7km long Tai Lam Tunnel of Route 3 at Kam Tin as seen in early 1996. Tai Lam Tunnel consists two main tunnels, each measures 15.5m wide and 10.5m high, and a 950m long servicing duct for ventilation and other supply purposes in between the main tunnels.



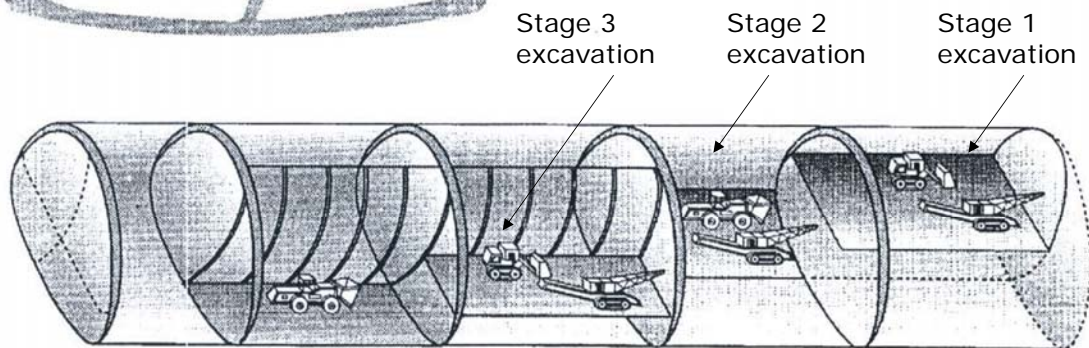
Entrance arrangement for a bypassing tunnel of the HK-Macau-Zhuhai Bridge at Chek Lap Kok



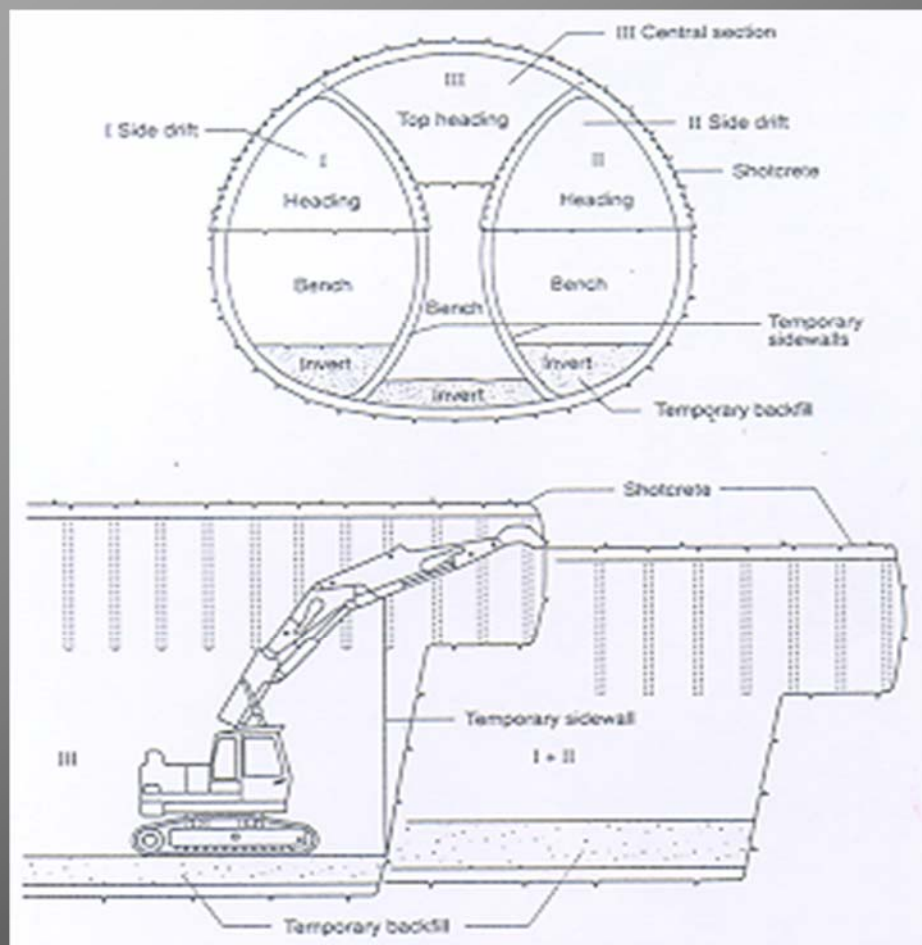
The portal with its entrance hood under construction



Construction of tunnel using the New Austrian Tunnel Method (NATM, mainly use in soft ground)



Drawing showing the excavation sequences using the New Austrian Tunnel Method. The principle of constructing large sectioned tunnel using this method is to subdivide the tunnel section into several arched smaller sections for the sake of easier control and safer supporting during excavation. The newly formed surfaces are often required to temporary supported by girder sections, shotcrete, nails or anchors.



(1) Left Pilot

(2) Right Pi

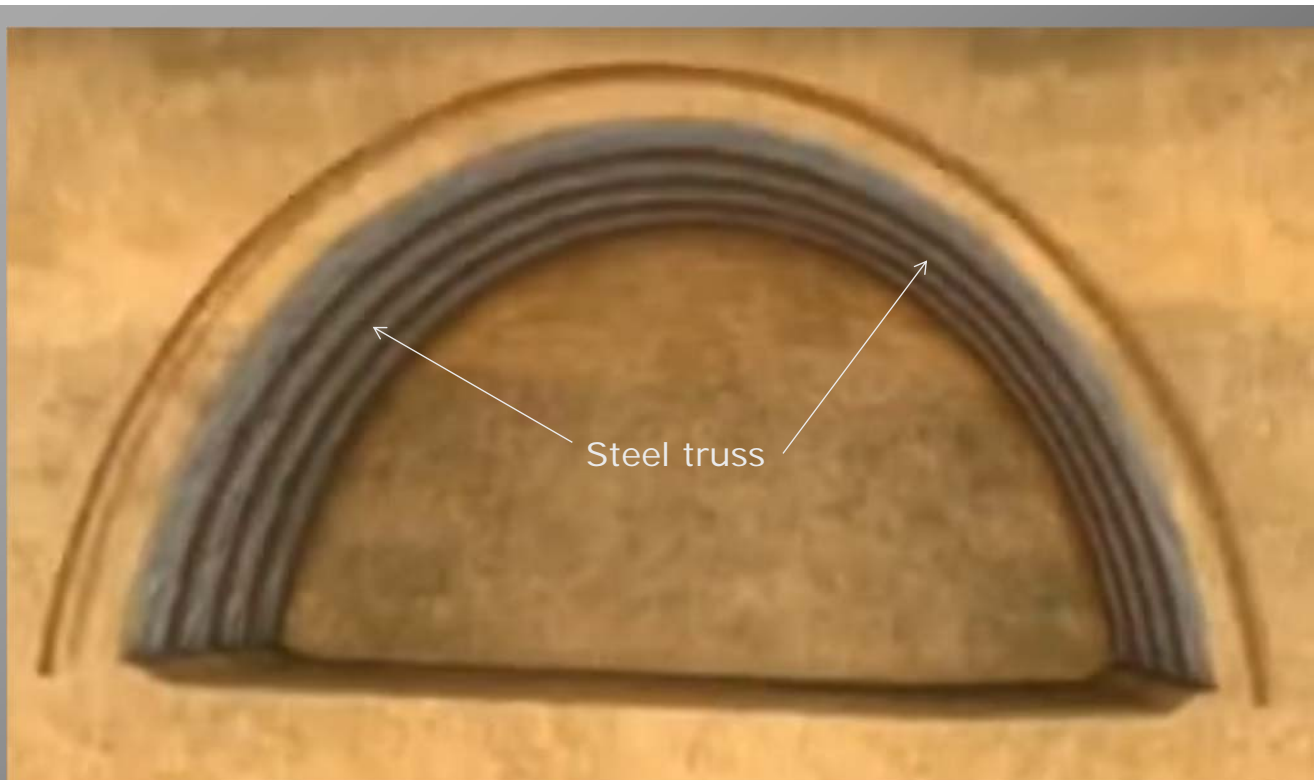


(4) Bottom Bench



A section of tunnel excavation using New Austrian Tunnel Method (NATM).

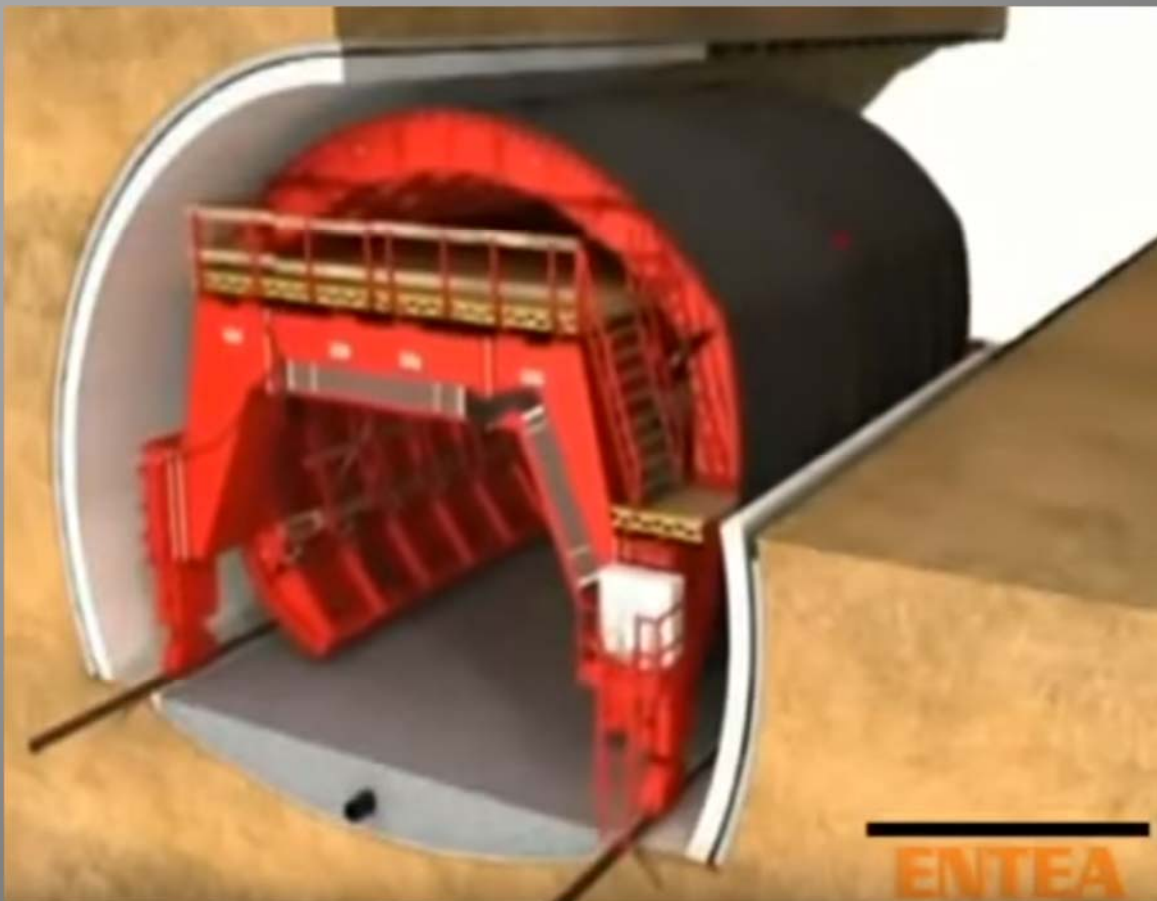




Excavate the upper part of the tunnels and support it with temporary steel truss and shotcrete it.

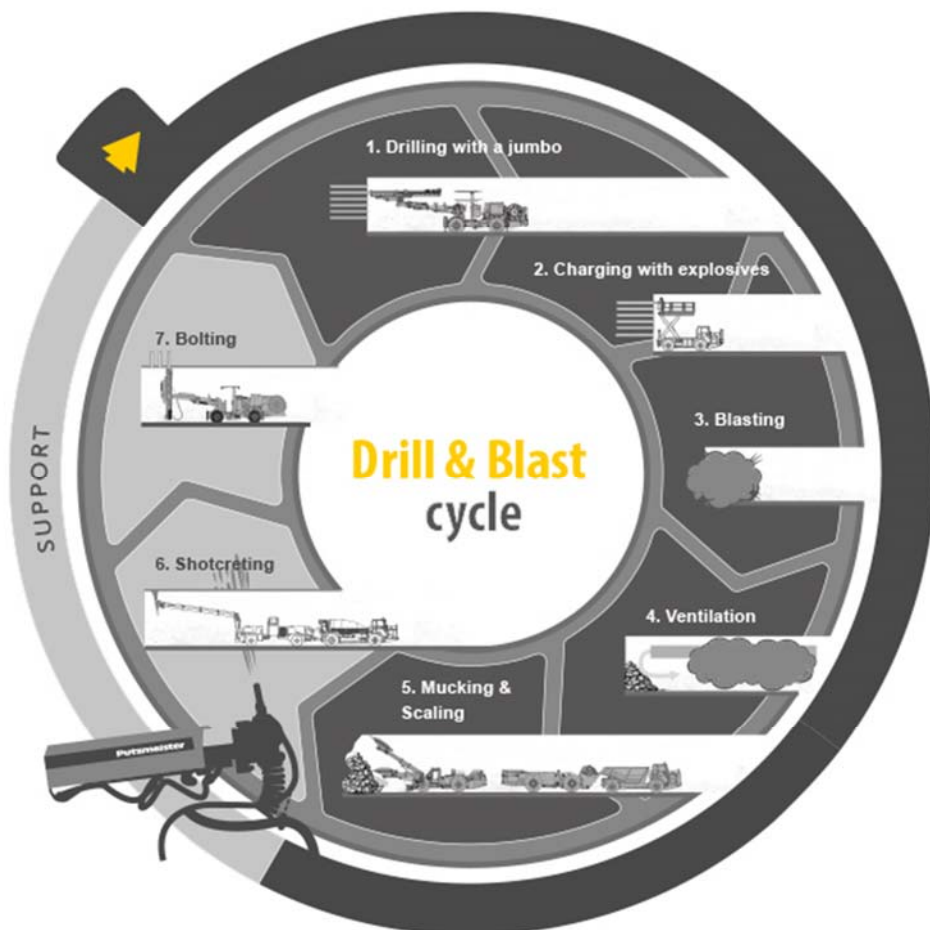
<https://www.youtube.com/watch?v=kKrA1ItM-dU>



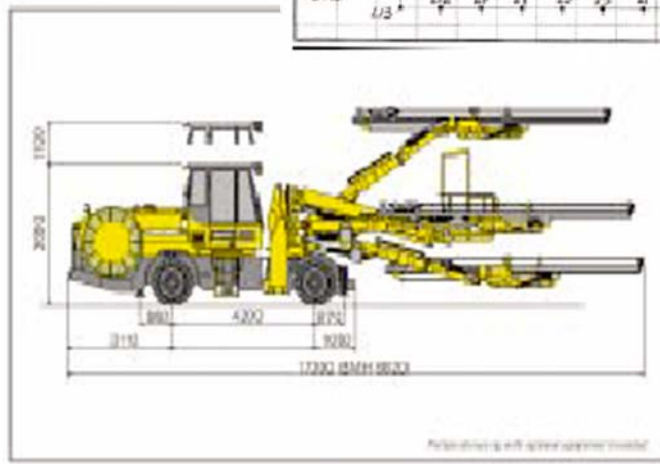
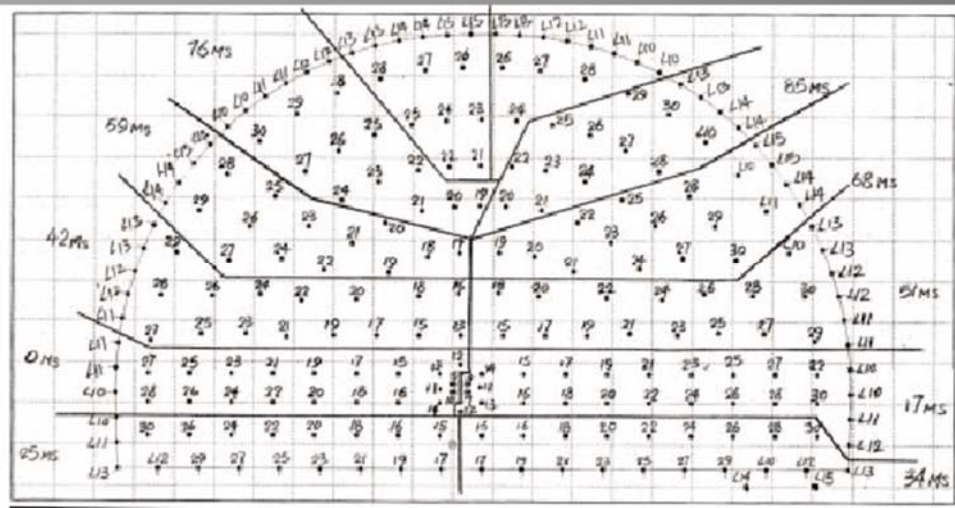


Finally use the tunnel lining gantry form to concrete the final tunnel lining

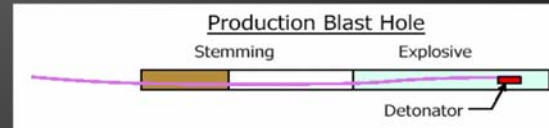
Tunnel constructed using Drill and Blast Method



Blast hole layout pattern



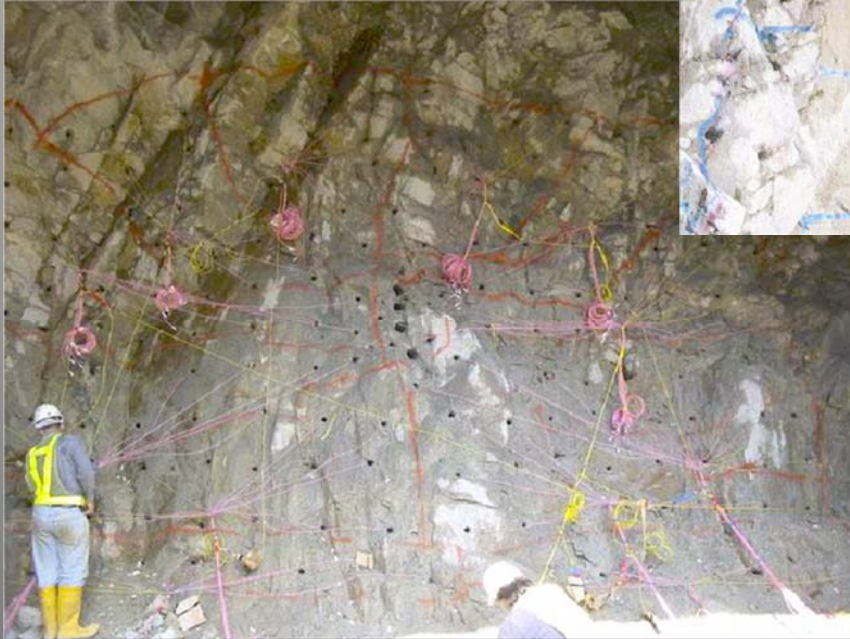
Machine use for the drilling of the blast hole



The machine, known as Jumbo tunneling machine, is used to drill and form holes inside the tunnel for the placing of explosive to activate the blasting. This machine is computer controlled and can drill 3 holes at the same time with direction or angle precisely set.



Placing explosive
into the blast hole



Excavating, Scaling
and removing of the
blasted section at
tunnel end



Tunnel tube formed and exposed surface temporary protected using shotcrete

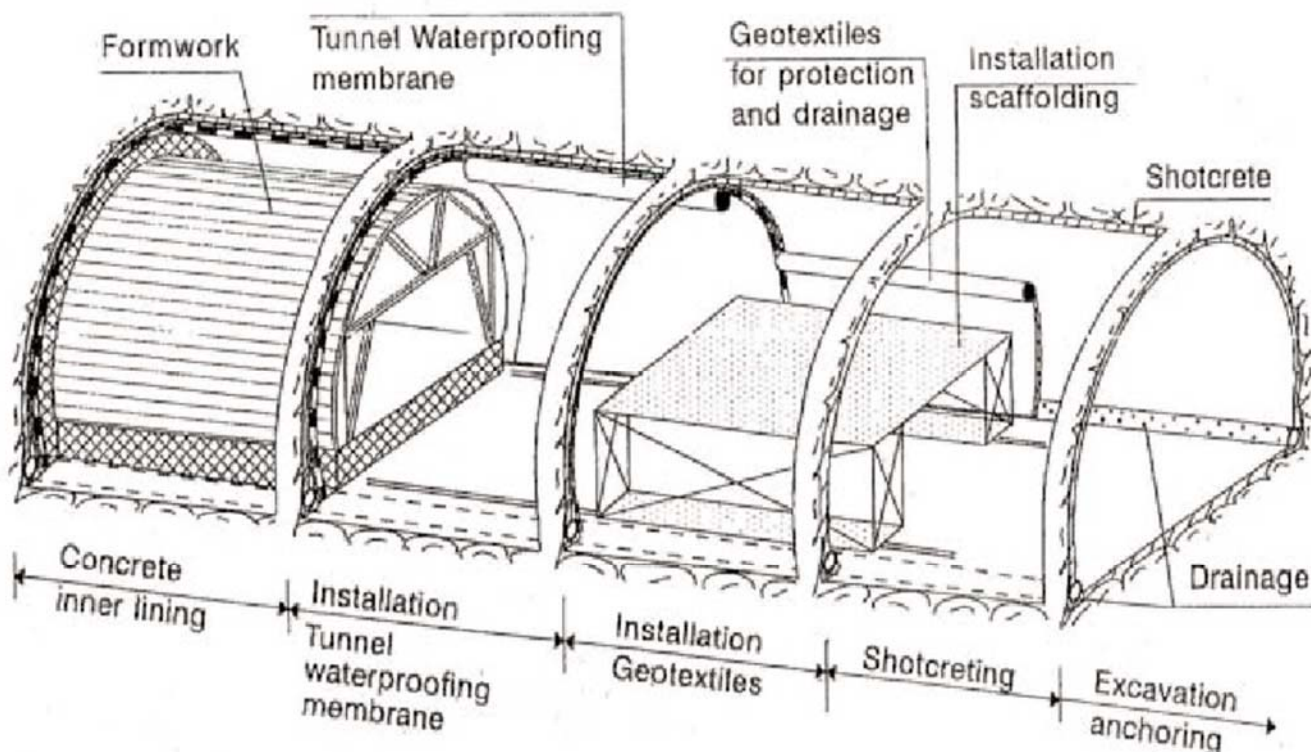


The erection of the gantry-type formwork for the forming of tunnel lining at entrance of the tunnel portal on Ting Kau side.



Detail look of the gantry-type formwork for the forming of tunnel lining

Construction sequence for tunnel waterproofing and permanent lining



Fixing of the reinforcement before the forming the tunnel lining



Forming the tunnel lining –
laying of waterproofing
membrane and fixing of
reinforcement bar before
concreting





After the tunnel formed by drill and blast process, the newly formed tunnel surface is to be lined with an in-situ concrete lining to stabilize the exposed soil or rock faces. The photo shows the gantry-type formwork used to form the in-situ concrete lining.



Interior of the Tai Lam Tunnel before paving. The installation of the service void by the use of a traveling-type formwork gantry

Traveling-type
formwork gantry to
form the ceiling
service void



Tunnel Construction using Tunnel Boring Machine (TBM)

Tunnel formed using TBM somewhat like forming a bore pile. It involves 3 similar operation, there are:

1. To drill a hole in the ground (one is vertical one is horizontal).
2. To remove the excavated material away from the hole.
3. To protect the side of excavation from collapsing.

Refer to this animation about operation of TBM

http://www.youtube.com/watch?feature=player_detailpage&v=yFHRl3HFMDg

http://www.youtube.com/watch?feature=player_detailpage&v=SsSlvH92Tl0



The tunnel boring machine for the forming of the 3.8m diameter tunnel tube on Butterfly Valley side.



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 immediate at the back of the cutting head.



Soil disposal wagons at the disposal area on Butterfly Valley side portal. The spoil will be kept at this location waiting for the removal 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 track heading to that direction. Rail track on the left is the depot and servicing centre for the soil disposal wagons, as well as for general loading and unloading purposes.



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 etc.

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, pushing forward, or even slight adjustment of its heading direction.



1 挖掘啟動豎井和回收井
Excavate launching shaft and retrieval shaft



2 在啟動豎井進行隧道鑽挖機裝嵌
Assemble the TBM at launching shaft



3 在地底鑽挖隧道
Cut and excavate the tunnel



4 鑽挖機抵達回收井
進行分拆然後運走
TBM arrives in retrieval shaft to be dismantled for transportation



Formation of the tunnel portal and
other logistic set-up to
facilitate the tunnel construction works
- The KCR West Rail Tsing Kwai Tunnel case



The formation of the tunnel portal for the Kwai Tsing Tunnel at Mei Foo side.



The tunnel portal gradually in shape.



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 equipments 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 assembling of equipments. This photo shows a traveling-type working gantry is being assembled inside the portal area of Kwai Tsing Tunnel at Mei Foo side.



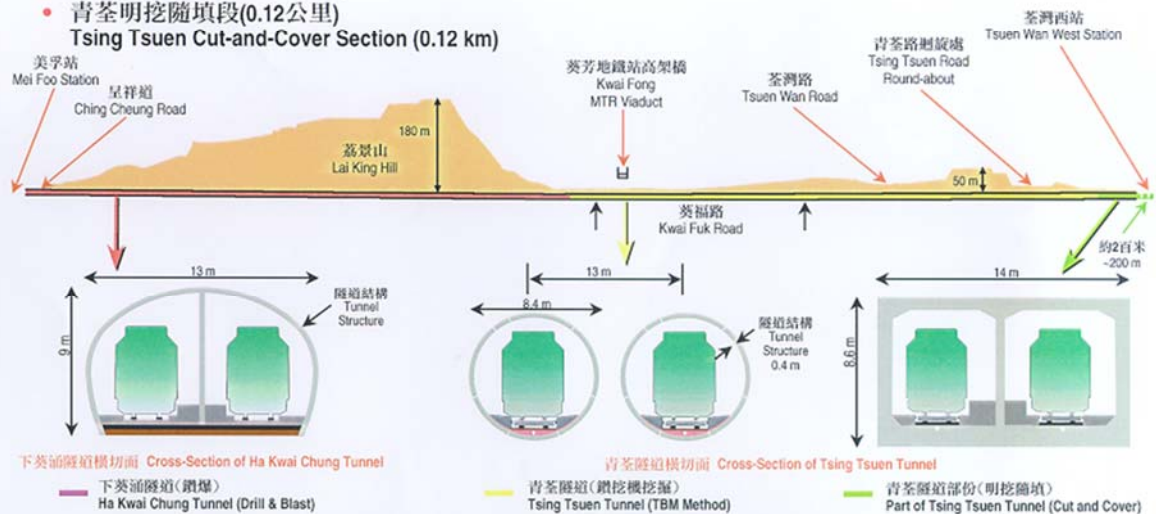
The finally completed 25-m wide tunnel entrance, cutting across about 10m above which, is the Lai King Hill Road. The formation of such a large void below a roadway can seriously endanger the stability of the road sub-structure. Note the waling and rock anchors above the entrance and the rib-form structure, a type of lattice girder beam, which helps to support the Lai King Hill Road above.



The jumbo tunneling machine at work to form the tunnel entrance.

葵青隧道—3.6公里 *Kwai Tsing Tunnels – 3.6 km*

- 下葵涌隧道(1.7公里)
Ha Kwai Chung Tunnel (1.7 km)
- 青荃隧道(1.78公里)
Tsing Tsuen Tunnel (1.78 km)
- 青荃明挖隨填段(0.12公里)
Tsing Tsuen Cut-and-Cover Section (0.12 km)



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 construction of the tunnels from Mei Foo to the shaft here at Lai King is by traditional drill and blast method. While for the section further on heading towards Tsuen Wan, a mixed-ground earth pressure balanced tunneling machine is employed for the forming of the tunnel.



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 stored at the work depot in Tsuen Wan.



A gantry crane serving in the depot at Tsuen Wan for the Kwan Tsing Tunnel project



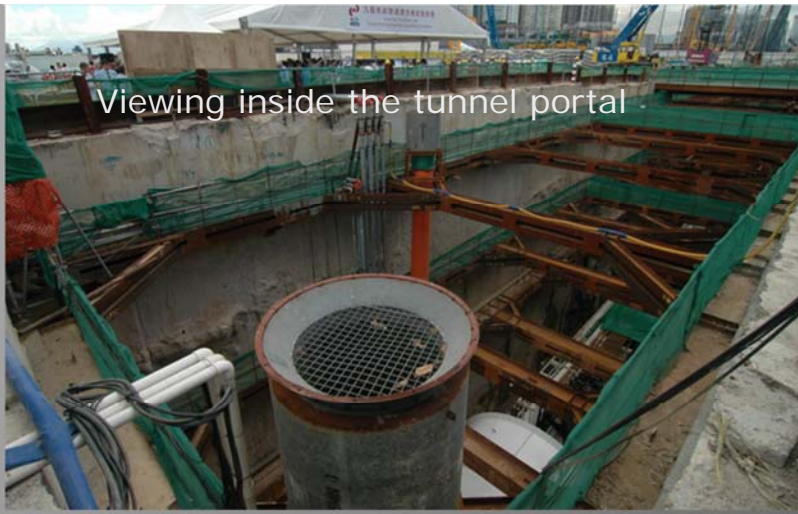
The shield of the EPBM being lowered into the shaft for onward assembly. The 8.7m diameter cutter head will later be connected to the front (on the left side) of the shield.



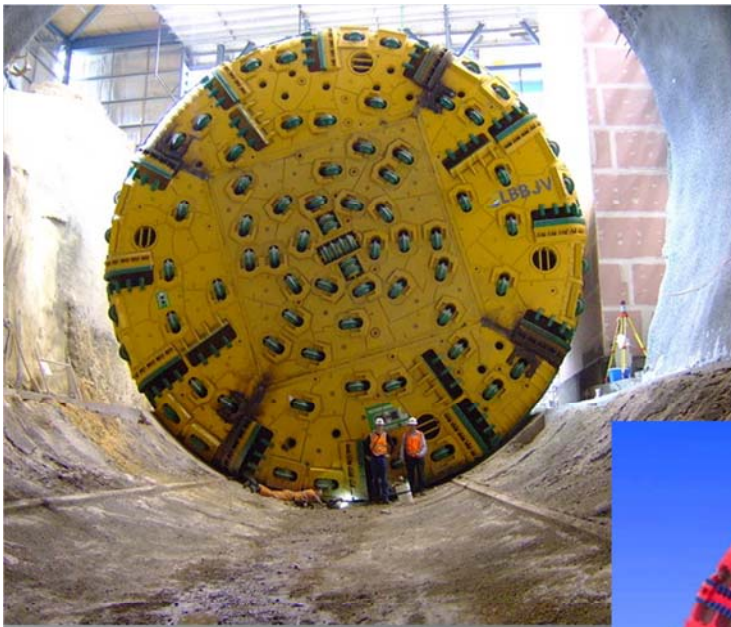
Another tunnel portal for a TBM operation for the MTR Kowloon Southern Link at Austin Road

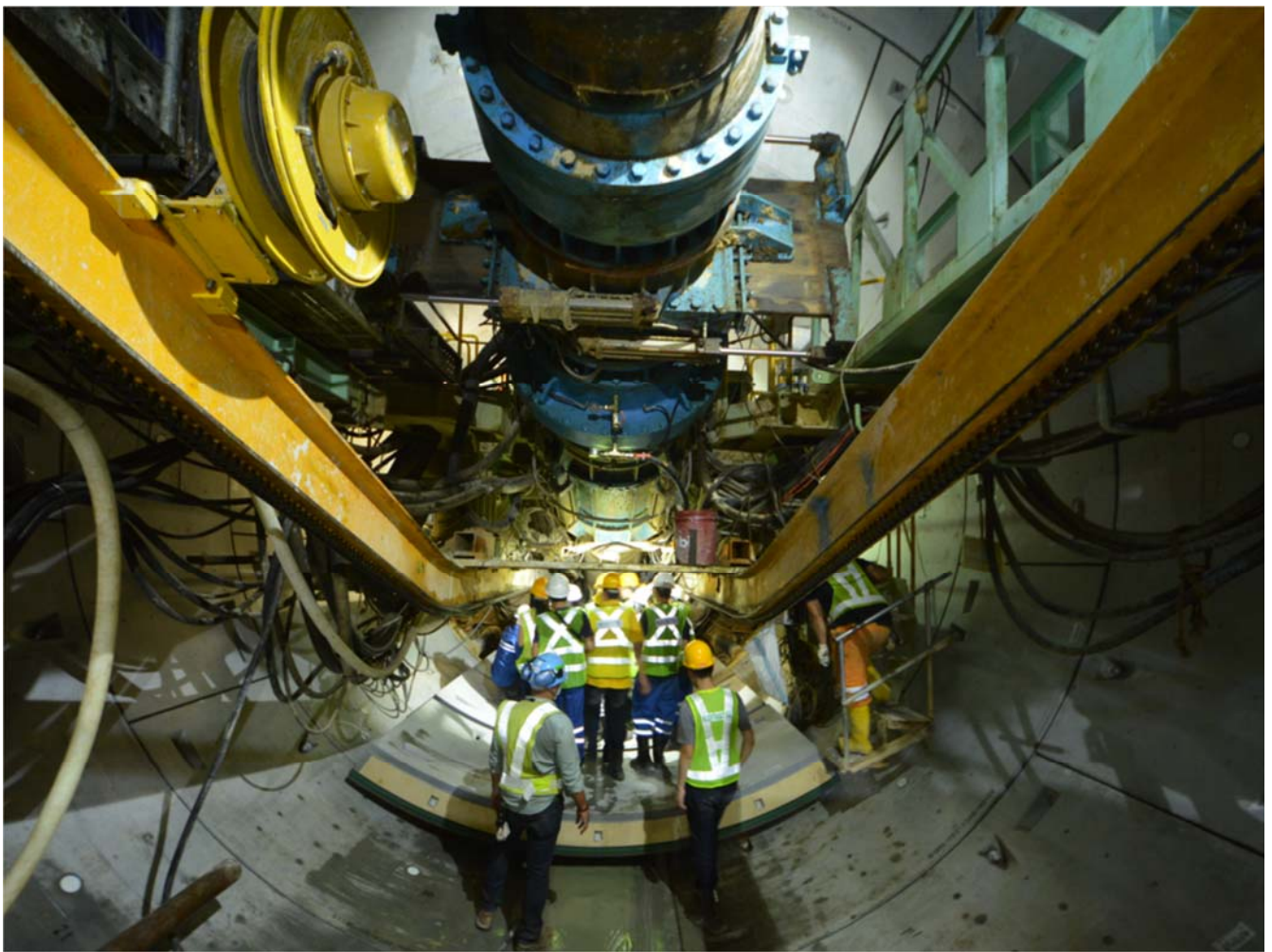


Viewing inside the tunnel portal



Tunnel Boring Machine (TBM)

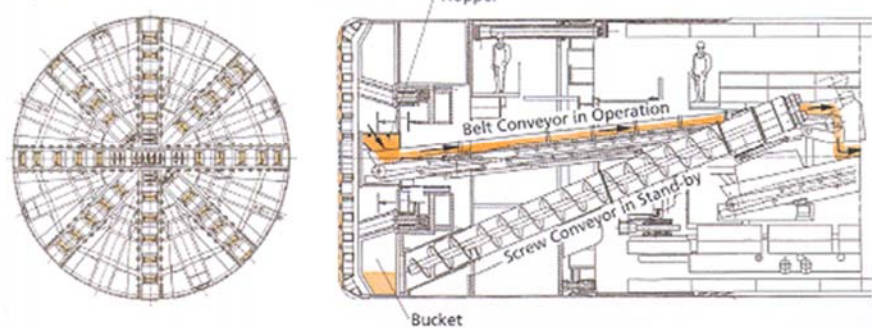




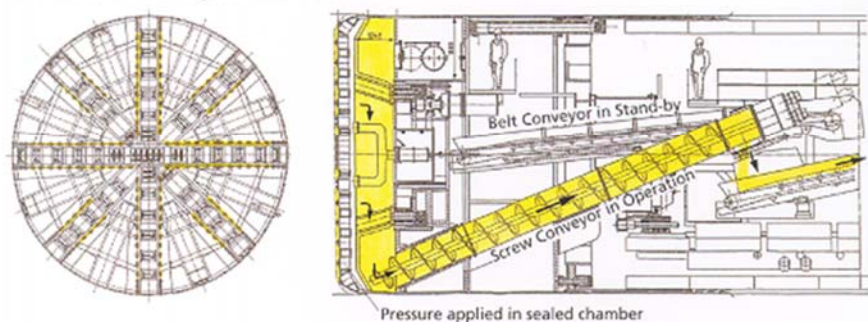


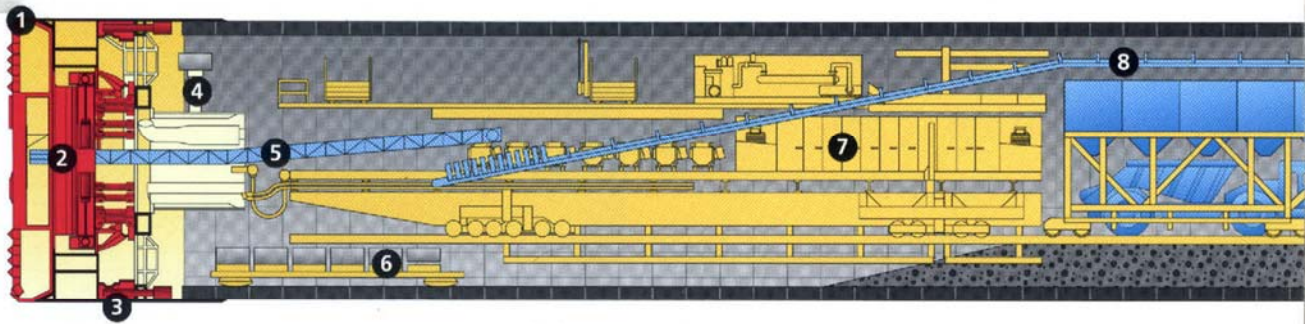
The working principle of the mixed-ground earth pressure balanced tunneling machine under the open mode and earth pressure balanced mode.

Open Mode for hard-rock excavation



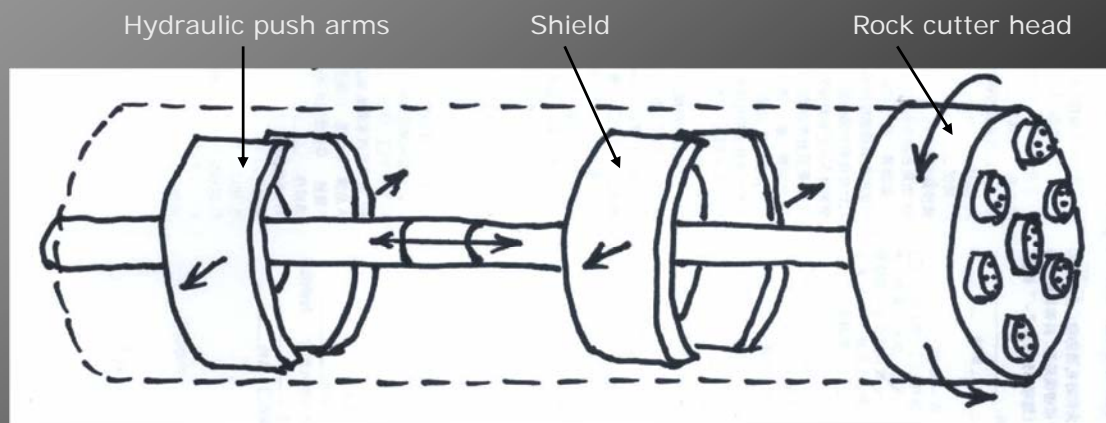
EPB Mode for Soft-ground excavation





Construction of TBM

- | | | |
|--------------------|-------------------|--------------------------|
| 1 Rock cutter head | 4 Erector | 7 Electrical switch gear |
| 2 Drive unit | 5 Conveyor I | 8 Conveyor II |
| 3 Push cylinder | 6 Segment handler | |



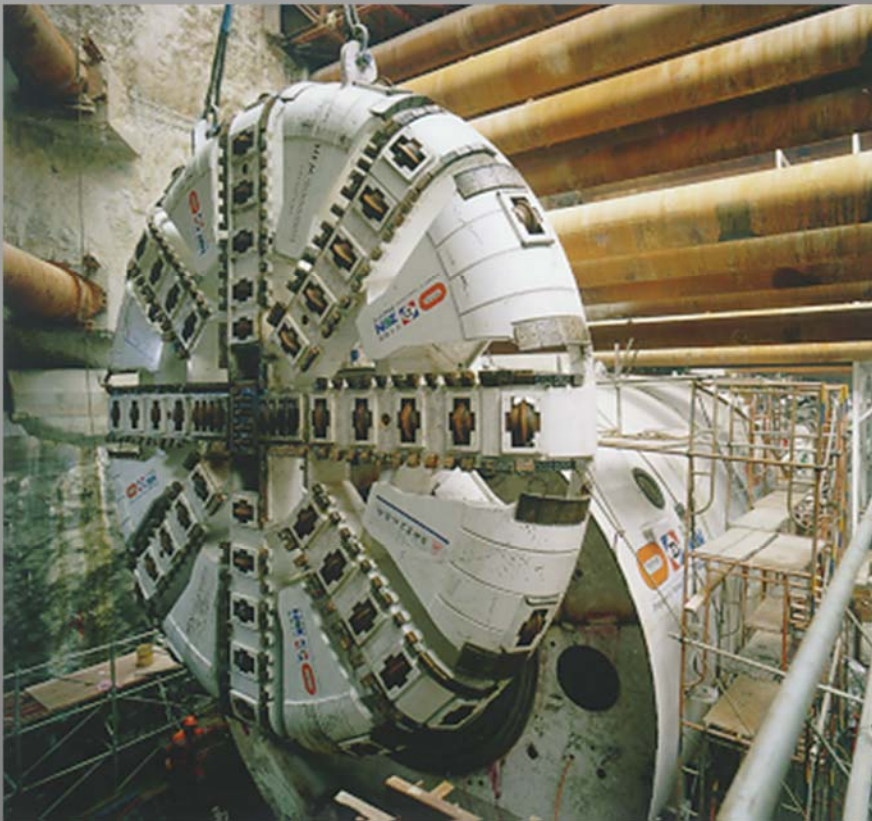
Another set of tunnel boring machine at the fabricating factory at Guangzhou in 2005 preparing for the tunnel work for the KCR Kowloon Southern Link project.

The trial assembly of the tunnel boring machine in 1998 at the fabricating factory at Shanghai before shipping to Hong Kong for final operation.





The trial assembly of the EPBM at the fabricating factory at Shanghai being shipping to Hong Kong.



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 are lateral support used to stabilize the 25m deep tunnel shaft.

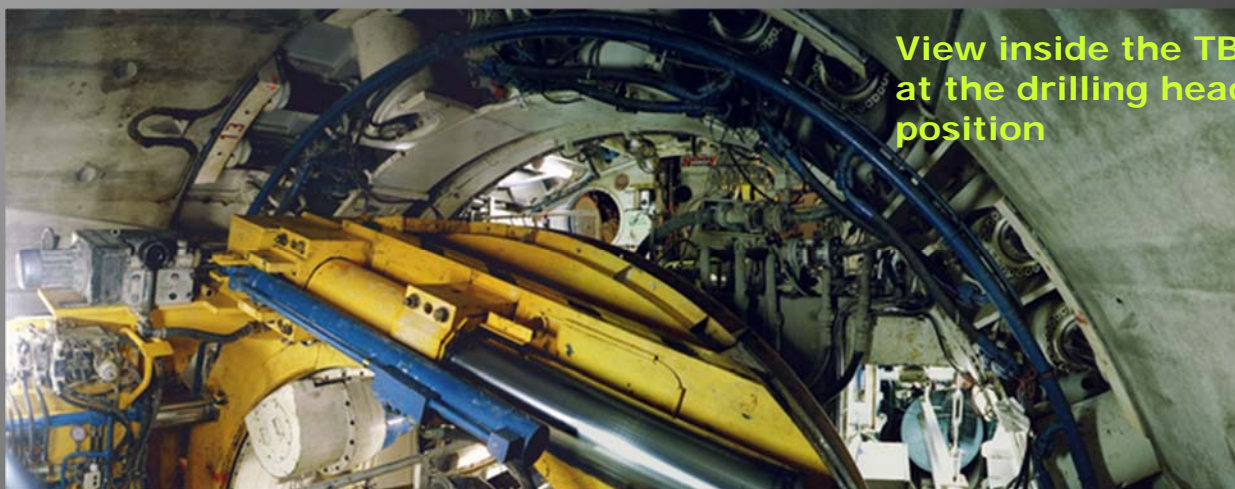


The overall view of the EPBM pictured at the Commissioning Ceremony of the machine on 31st March 2000.



Tunnel portal leading into the tunnel tube formed by the TBM

http://www.youtube.com/watch?feature=player_detailpage&v=4i4DSvRoKQc



View inside the TBM at the drilling head position

Formation of the tunnel portal and
other logistic set-up to
facilitate the tunnel construction works
- The KCR West Rail Tai Lam Tunnel case

Tai Lam Tunnel of KCR West Rail is a 5.5km long tunnel linking Tsuen Wan to Kam Tin and is constructed using drill and blast method. The photo shows the early stage of forming the tunnel portal along Hoi Hing Road at Chai Wan Kok, Tsuen Wan.



Portal of Tai Lam Tunnel at Chai Wan Kok viewed towards the Tuen Mun Highway direction. The elevated bridges in the far background are the main connecting bridges at the entrance to Tuen Mun Highway. The tunnel will cut through the foundation of one of the elevated bridges. Underpinning work to the foundation is thus required before the proceeding of 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.



Tunnel entrance under Tuen Mun Highway

Tunnel end preparing for the drilling and insertion of explosive





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.



The portal arrangement of Tai Lam Tunnel at Kam Tin side.



An axial fan installed to provide ventilation for the 5.7km long Tai Lam Tunnel



Interior view of the Tai Lam Tunnel. The plastic lining on the tunnel faces is water- proofing membrane which helps to prevent the leaking of water into the tunnel interior through the concrete lining. The nylon hose on the right side of tunnel is the ventilation hose, on the left is the conveyor system for the removal of spoils.



The gantry type scaffold that used to install the waterproofing membrane. Majority of servicing equipments working inside tunnels are track mounted and constructed in gantry form to fit the section of the tunnel interior.



An overall view of the tunnel lining formwork gantry used to form the in-situ concrete lining of the tunnel.



The tunnel interior with the in-situ concrete lining already been placed.

Tunnel Construction
using Cut-and-Cover Method
(Airport Railway at Central Reclamation)



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 the Hong Kong Station and the immersed tube harbour crossing tunnel is formed using 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 struttled with steel tube and soldier piles wall supported using ground anchors are both used to form the cut-off systems during the excavation of the tunnels.



The approach tunnels basically 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 housed the flood gate and other control and electrical gears for the tunnel system. From that 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.





Section of the tunnel pit formed by soldier pile wall and laterally supported by anchors. The structure of the approach tunnel have basically been completed pending for backfilling at a later stage.

**Tunnel Construction
using Cut-and-Cover Method
(MTR Tseung Kwan O Line)**



Large amount of cut-and-cover tunnels were constructed in the MTR Tseung Kwan O Line in the reclaimed land of TKO New Town



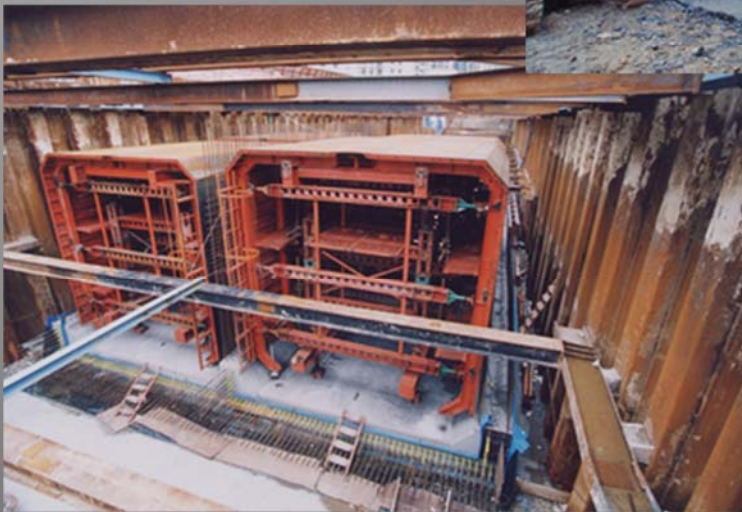
Cut-and-cover tunnel constructed in difficult environment





Cut-and-cover tunnel
constructed in hard rock zone

Box-section tunnel
tube was constructed
inside the tunnel
trench using a set of
traveling-type tunnel
formwork



Tunnel Construction using Cut-and-Cover Method (KCR Kowloon Southern Link)



Section making use of cut-and-cover method to construct

Alignment of the Kowloon Southern Link from Tsim Sha Tsui to Nam Chong



Tunnel section near Jordan with the cut-off walling support already installed before the commencement of excavation in full scale



Note: the tunnel needs special traffic diversion arrangement when cutting across existing roadway

Tunnel section near Jordan/Tsim Sha Tsui with the cut-and-cover tunnel trench being formed down to the formation level (part of the future West Kowloon Station)



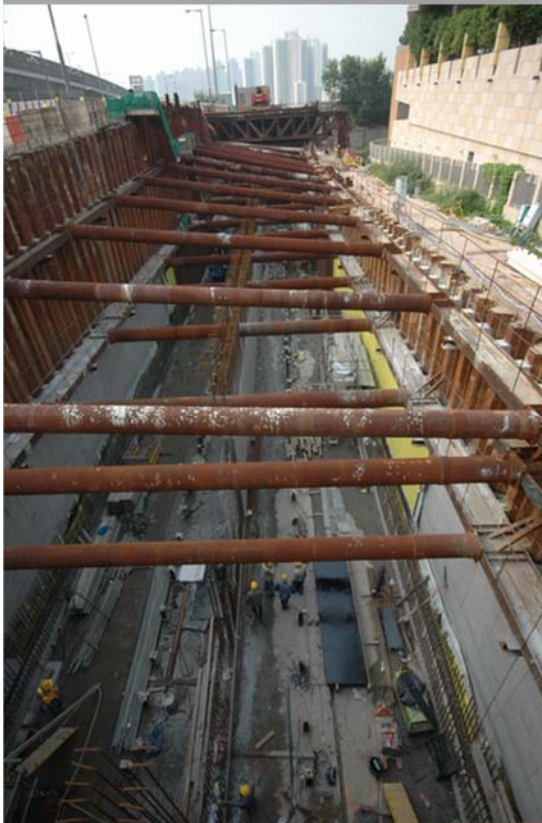


→ Alignment
of tunnel

Tunnel section along Jordon/Tai
Kok Tsui (excavation up to
about half of formation level)



Tunnel trench crossing main
water pipes and flyovers



Tunnel section between
Olympus Station and
Nam Chong Station



Falsework for work platform and access opening for work and handling of materials/equipments

Excavation halfway to the formation level



Excavation at various stages



Excavation just commenced



Excavation completed down to the formation level and construction started for the tunnel structure using in-situ method



Tunnel excavation and construction - crossing under an existing highway bridge with limited headroom and congested working environment

crossing under an existing storm water discharge culvert

Large-size storm water discharge culvert

Tunnel tube under construction

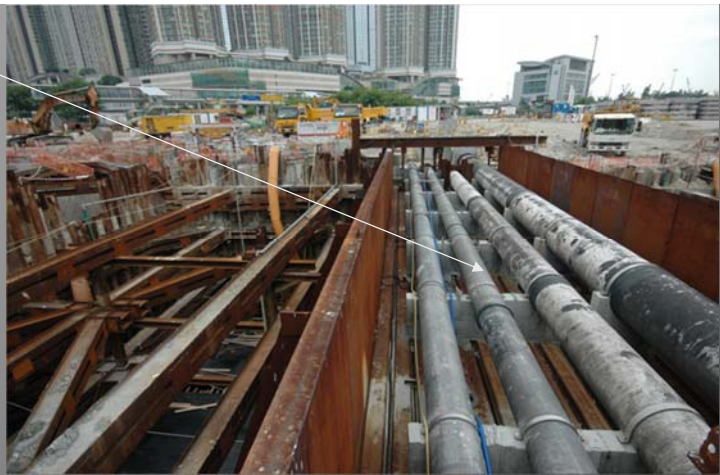
Tunnel working under very difficult condition



Temporary road deck supported by shoring

Tunnel working under very difficult condition - crossing under busy surface roadway

Existing large dia.
water main



Foundation for
existing pedestrian
footbridge



Tunnel working under very
difficult condition - crossing
congested underground service



Construction of the tunnel using in-situ method

using in situ method

Tunnel Construction using Immersed Tubes



Western Harbour Crossing is constructed using precast concrete immersed tube sections. A total of 12 sections have been used, each measures 113m x 33.5m x 8.5m high and weighs about 35,000 tons. The photo shows one of the 3 batches of immersed tubes being formed in the casting yard at Shek O, HK

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 being connected, the water embraced by the elbowing land would be 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.

http://www.youtube.com/watch?feature=player_detailpage&v=RZf3rMigAfc





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.



Construction of the tunnel approach on both side of the Western Harbour Crossing



Associate works of the finished tunnel – the approach tunnel and the connecting roadwork



Construction of the immense-tube for the HK-Zhuhai-Macao Bridge

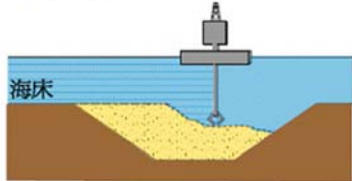




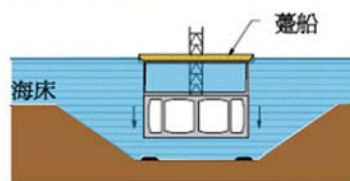
Size of each tunnel tube:
180m x 11.5m x 38m,
weight 72000 tons

Cast by incremental
launching methods in 6
segments

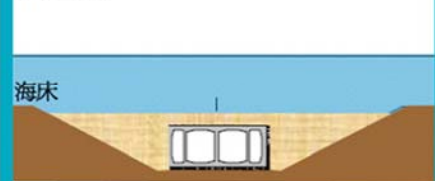
(1) 挖掘坑道



(2) 安放沉管组件



(3) 回填



Tunnel Construction

Final Finishes and Fitting-out



**Tunnel Section –
forming of the
accessible service
void**



**Covering of the
tunnel wall and
paving work**

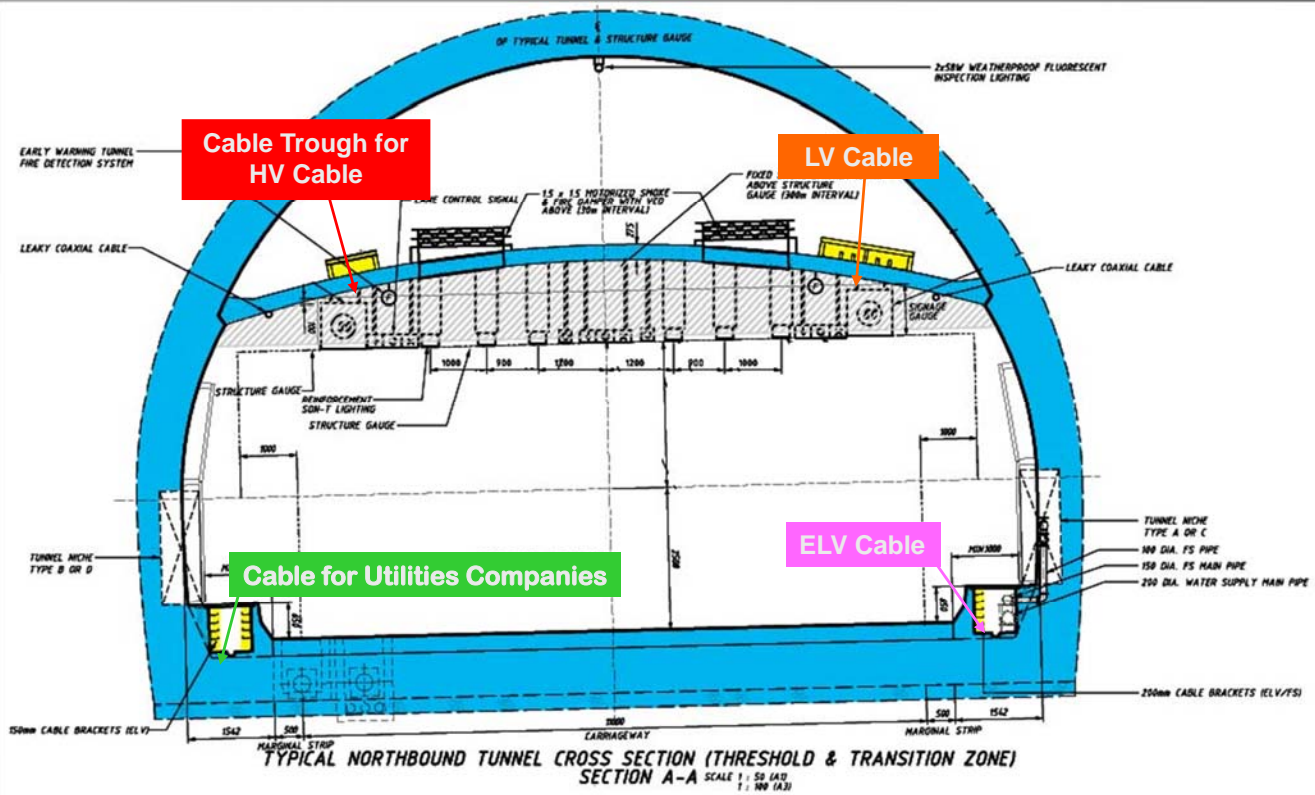
Concrete Pavement Construction



Completed Tunnel Lining



E&M facilities in a Tunnel



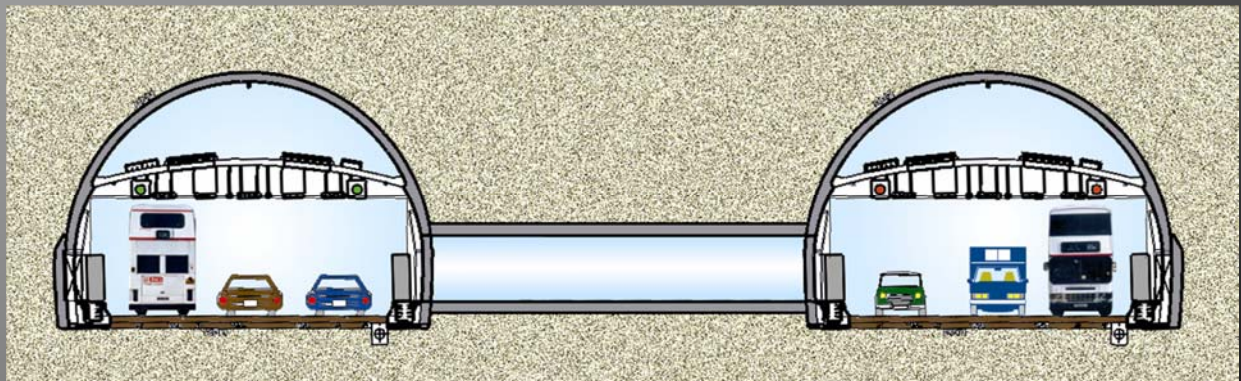
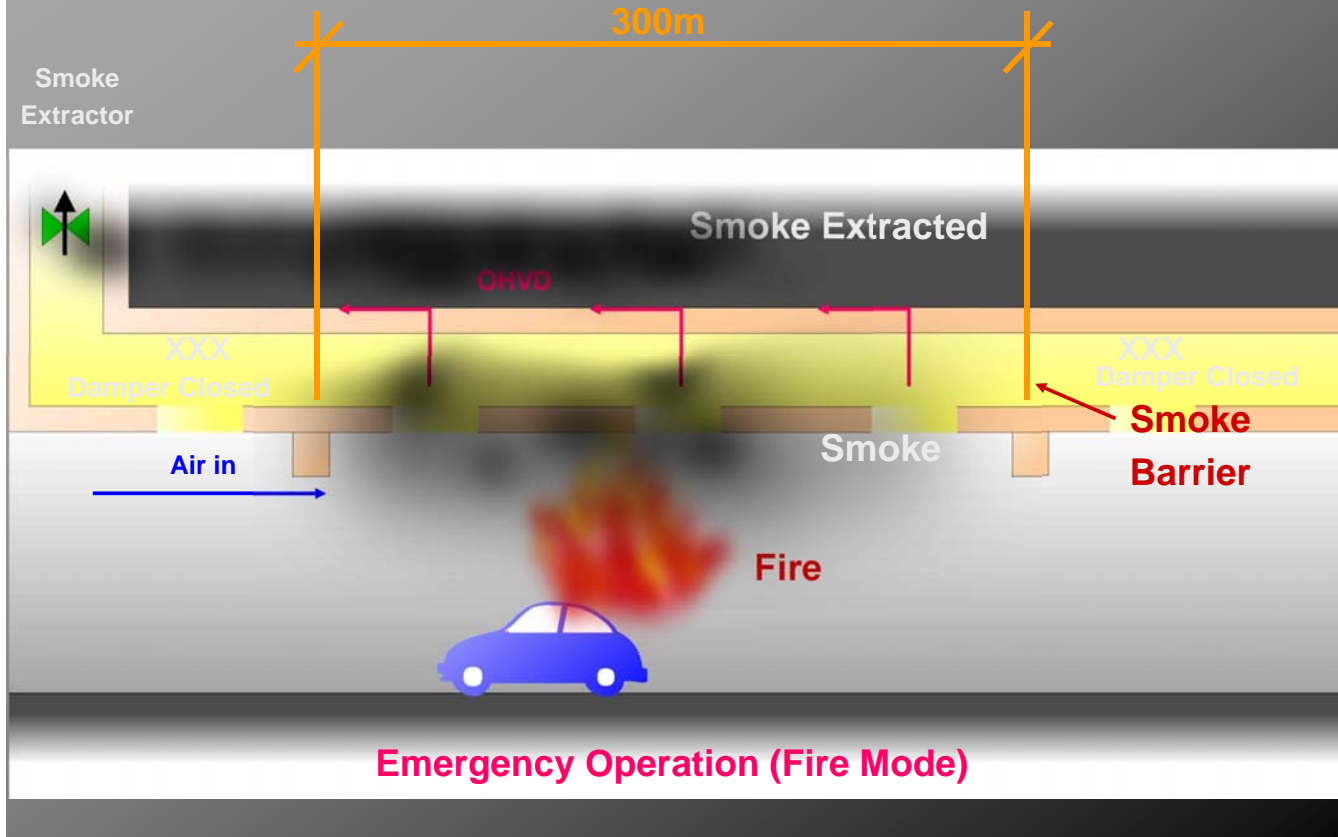
Fitting out of the tunnel interior and services installation



**Installation of the
tunnel wall panel**

Fire and emergency
provision for tunnel

Tunnel Ventilation forms a major part of fire control system. It extracts the smoke generated from fire accident



Tunnel emergency exist forming part of the safety provision within tunnel

Laying of rail track in railway tunnel and a fire resisting separating wall



End of presentation