

Brief description of tunnelling technologies

Open Face TBM

This is a mechanised tunnelling method in which slurry is used to balance the pressure at the face of the TBM.

Advantages

- Limits ground settlement and produces a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes it suitable to use in heavily urbanized areas
- Simple technology
- Ideal for short drives

Disadvantages

- The major disadvantage is the upfront capital cost. TBMs are expensive to construct, difficult to transport, require significant backup systems and power.
- Requires stable ground and manageable ground water seepage rates
- Limited ability to safely advance at maximum speed through unstable ground conditions

Main characteristics

- Tunnel Lining – Precast Concrete Segments
- Typical Performance - 1m to 5m per day. Actual performance and costs will depend on ground conditions and tunnel diameter
- Typical Costs – USD 33,300 to USD 49,600 per metre

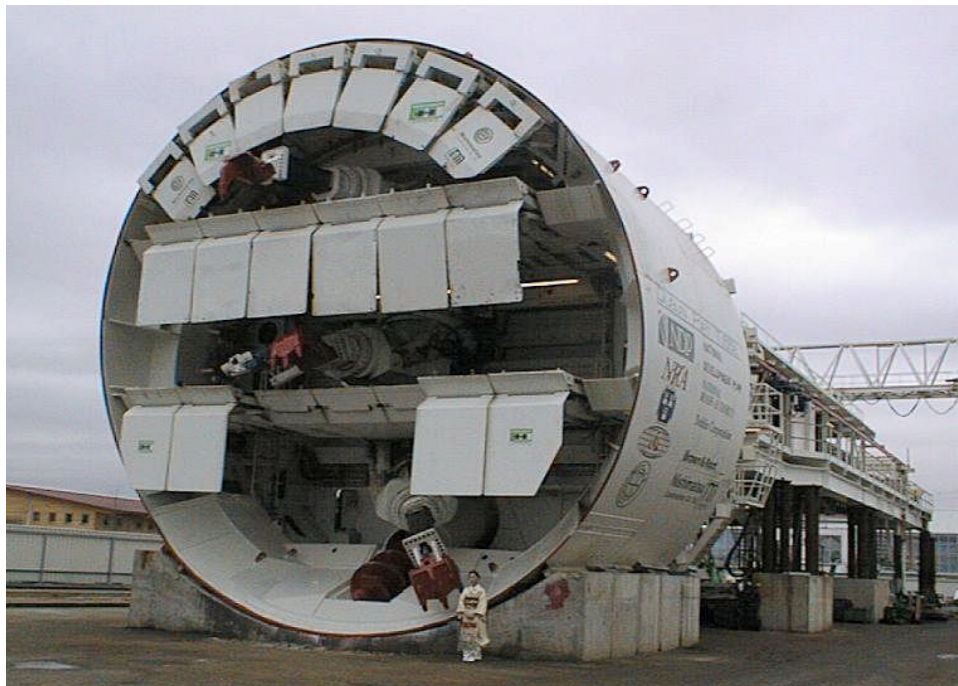


Figure 1 Typical Open Face TBM

Slurry Pressure Balance (SPB) TBM

The basic principle of this TBM is to maintain the face pressure during the excavation phase by filling the working chamber, located behind the cutter head, with slurry.

Advantages

- Allows soft, wet, or unstable ground to be tunnelled with a speed and safety not previously possible
- Suitable for ground with high water pressures (below water table)
- Limits ground settlement and produces a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes it suitable to use in heavily urbanized areas

Disadvantages

- The major disadvantage is the upfront capital cost. TBMs are expensive to construct, difficult to transport, require significant backup systems and power.
- Drive can be hindered by large stones and boulders

Main characteristics

- Tunnel Lining – Precast Concrete Segments
- Typical Performance - 5m to 30m per day. Actual performance and costs will depend on ground conditions and tunnel diameter.
- Typical Costs – USD 7,106 to USD 47,036 per metre



Figure 2 **Slurry TBM**

Earth Pressure Balance (EPB) TBM

This is a mechanised tunnelling method in which spoil is admitted into the tunnel boring machine (TBM) via a screw conveyor arrangement which allows the pressure at the face of the TBM to remain balanced without the use of slurry.

Advantages

- Allows soft, wet, or unstable ground to be tunnelled with a speed and safety not previously possible
- Limits ground settlement and produces a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes it suitable to use in heavily urbanized areas

Disadvantages

- The major disadvantage is the upfront capital cost. TBMs are expensive to construct, difficult to transport, require significant backup systems and power.

Main characteristics

- Tunnel Lining – Precast Concrete Segments
- Typical Performance - 9m to 35m per day. Actual performance and costs will depend on ground conditions and tunnel diameter.
- Typical Costs – USD 6,460 to USD 42,760 per metre

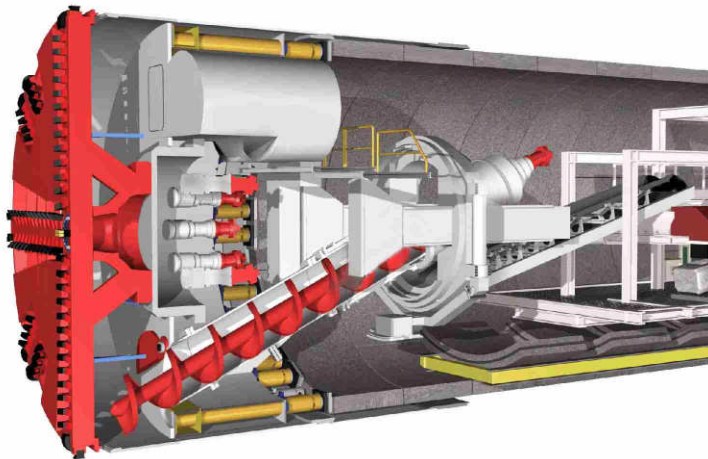


Figure 3 Cross-Section through Earth Pressure Balanced TBM



Figure 4 Earth Pressure Balanced TBM

Hard Rock TBM

This method involves the use of a Tunnelling machine with a shield and cutter head suitable for hard rock

Advantages

- They offer a continuous and controlled means of tunnelling capable of high rates of advance under favourable conditions.

Disadvantages

- The major disadvantage is the upfront capital cost. TBMs are expensive to construct, difficult to transport, require significant backup systems and power.
- Their applicability is limited to long tunnels where the high rates of advance and tunnel quality can offset their high capital cost.

Main characteristics

- Tunnel Lining – Precast Concrete Segments / Sprayed Concrete / No lining
- Typical Performance - 12m to 67m per day. Actual performance and costs will depend on ground conditions and tunnel diameter
- Typical Costs – USD 3,300 to USD 33,075 per metre



Figure 5 **Hard Rock TBM**

Drill & Blast

Before the advent of tunnel boring machines, drilling and blasting was the only economical way of excavating long tunnels through hard rock, where digging is not possible

Drilling and blasting works as follows:

1. A number of holes are drilled into the rock, which are then filled with explosive.
2. Detonating the explosive will cause the rock to collapse and thus lengthen the tunnel.
3. Rubbles are removed and new tunnel surface are reinforced.
4. Repeating these steps will eventually result in a tunnel.

The positions and depths of the holes (and the amount of explosive each hole receives) are determined by a carefully constructed pattern, which, together with the correct timing of the individual explosions, will guarantee that the tunnel will have an approximately circular cross-section.

Advantages

- Suitable for Hard rock where digging is not possible
- Its flexibility, mobility, and low capital cost constitute real advantages in many situations, such as those involving short lengths of tunnel or low rates of advance.

Disadvantages

- There is a high risk of over breaking the tunnel profile and damaging the surrounding rock
- High levels of noise and vibration make this unsuitable for an urban area.

Main characteristics

- Tunnel Lining – Sprayed Concrete / Rock Bolts / No lining
- Typical Performance – 0.1m to 1m per day. Actual performance and costs will depend on ground conditions and tunnel diameter
- Typical Costs – USD 11,040 to USD 31,150 per metre



Figure 6 Typical Drill & Blast Tunnel

NATM / SCL / SEM

The New Austrian Tunnelling Method (NATM) is also known as Sprayed Concrete Lining (SCL) or Sequential Excavation Method (SEM). NATM involves lining the walls of an excavated tunnel with wire mesh, then spraying them with quick-drying concrete. A second concrete lining can be installed later.

NATM was developed between 1957 and 1965 in Austria. The main idea is to use the geological stress of the surrounding soil mass to stabilize the tunnel itself.

Advantages

- Eliminates the need for using some expensive TBM equipment during excavation
- Suitable for a wide range of geometry (shafts, junctions, non-circular tunnels and tunnels with variable shapes)

Disadvantages

- Its suitability diminishes in softer ground, which can subside when excavated
- Not suitable below water table in highly permeable soils

Main characteristics

- Tunnel Lining – Sprayed Concrete
- Typical Performance - 1m to 3m per day. Actual performance and costs will depend on ground conditions and tunnel diameter
- Typical Costs – USD 9,700 to USD 88,525 per metre



Figure 7 **Sprayed Concrete**



Figure 8 **NATM Tunnel**