Underground Mining of Metalliferous Deposits
Professor. Kaushik Dey
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture No. 20
Horizontal Drivages – III

HORIZONTAL DRIVAGE

There are basically two ways to construct the drift in underground excavation.

Drilling and blasting method

Mechanical cutting technique

Mechanical cutting technique

Tunnel Boring Machine (TBM)

The tunnel boring machine is a machine which has been developed in recent years and has revolutionized the tunnelling industry both making tunnelling a safer, more economic solution for creating underground space and opening the possibility of creating tunnels where it was not feasible before.

History

The first successful tunnelling shield which is commonly regarded as the forerunner of the tunnel boring machine was developed by Sir Marc Isambard Brunel to excavate the Rotherhithe tunnel under the Thames in 1825. However, this was only the invention of the shield concept and did not involve the construction of a complete tunnel boring machine, the digging still having to be accomplished by the then standard excavation methods using miners to dig under the shield and behind them bricklayers built the lining. The very first actual boring machine ever reported to have been built is thought to be Henri-Joseph Maus' Mountain Slicer designed in 1845 dig the Fréjus Rail Tunnel between France and Italy through the Alps, Maus had it built in 1846 in an arms factory near Turin. It basically consisted of more than 100 percussion drills mounted in the front of a locomotive-sized machine, mechanically power-driven from the entrance of the tunnel, however it was not used, and the tunnel was finally built using conventional methods. In the United States, the first boring machine to have been built was used in 1853 during the construction of the Hoosac Tunnel. Made of cast iron, it was known as Wilson's Patented Stone-Cutting Machine, after its inventor Charles Wilson. It drilled 10 feet into the rock before breaking down and the tunnel had to be completed many years later, using less ambitious methods. After nearly 100 years, James S. Robbins built a machine to dig through what was the most difficult shale to excavate at that time, the Pierre Shale. Robbins built a machine that was able to cut 160 feet in 24 hours in the shale, which was ten times faster than any other digging speed at that time. The modern breakthrough that made tunnel boring machines efficient and reliable was the invention of the rotating head, conceptually based on the same principle as the percussion drill head of the Mountain Slicer of Henri-Joseph Maus, but improving its efficiency by reducing the number of grinding elements while making them to spin as a whole against the soil front. Initially, Robbins' tunnel boring machine used strong spikes rotating in a circular motion to dig out of the excavation front, but he quickly discovered that these spikes, no matter how strong they were, had to be changed frequently as they broke or tore off. By replacing these grinding spikes with longer lasting cutting wheels this problem was significantly reduced. Since then, all successful modern tunnel boring machines use rotating grinding heads with cutting wheels for boring through rock.

TUNNEL BORING MACHINE – Types

The description of the types of TBM derive from what type of soil is being excavated.

Slurry Machine

Earth pressure Balance machine

Rock Machine

Slurry Machine

This is used for soils usually of varying hardness. The excavated soil is mixed with slurry to create positive face pressure required to sustain the excavation. This is known as a closed machine. The system for the removal of the soil involves pumping the soil mixed with slurry to plant located outside the tunnel that separates the slurry from the muck allowing its recirculation.

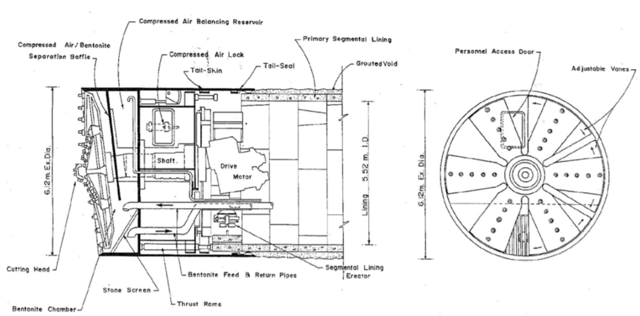

Figure 1. TBM Slurry machine

Earth pressure Balance machine

This is a closed machine and is used usually for softer fairly cohesive soils. In this case the positive face pressure is created by the excavated ground that is kept under pressure in the chamber by controlled removal through the rotation of the screw conveyor. The muck is thereafter removed by a conveyor belt and/or skips.

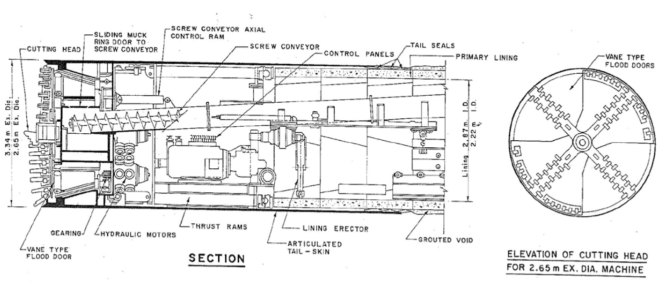

Figure 2. Earth pressure balance machine

Rock Machine

This is used for excavating rock. The rock is crushed by the cutters (often discs) and removed on conveyors and/or skips. Cutters are specifically designed to resist hard abrasive material.

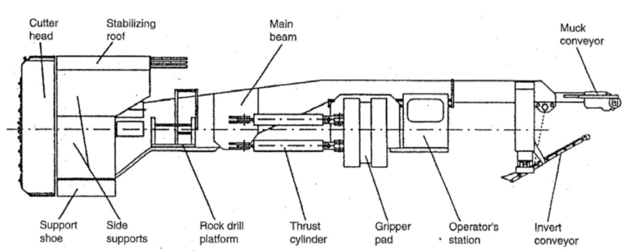

Figure 3. Rock machine

TUNNEL BORING MACHINE – Description

A tunnel boring machine (TBM) typically consists of one or two shields (large metal cylinders) and trailing support mechanisms. At the front end of the shield is a rotating cutting wheel. Behind the cutting wheel is a chamber. The chamber may be under pressure (closed machine) of open to the external pressure (open machine)

Behind the chamber there is a set of hydraulic jacks supported by the finished part of the tunnel which push the TBM forward. The rear section of the TBM is braced against the tunnel walls and used to push the TBM head forward. At maximum extension the TBM head is then braced against the tunnel walls and the TBM rear is dragged forward.

Behind the chamber there is a set of hydraulic jacks supported by the finished part of the tunnel which push the TBM forward. The rear section of the TBM is braced against the tunnel walls and used to push the TBM head forward. At maximum extension the TBM head is then braced against the tunnel walls and the TBM rear is dragged forward.

Behind the shield, inside the finished part of the tunnel, several support mechanisms which are part of the TBM are located: soil/rock removal, slurry pipelines if applicable, control rooms, and rails for transport of the precast segments.

The cutting wheel will typically rotate at 1 to 10 rpm (depending on size and stratum), cutting the rock face into chips or excavating soil (usually called muck by tunnelers). Depending on the type of TBM, the muck will fall onto a conveyor belt system or into skips and be carried out of the tunnel, or be mixed with slurry and pumped back to the tunnel entrance.

Depending on rock strata and tunnel requirements, the tunnel may be cased, lined, or left unlined. This may be done by bringing in precast concrete sections that are jacked into place as the TBM moves forward, by assembling concrete forms, or in some hard rock strata, leaving the tunnel unlined and relying on the surrounding rock to handle and distribute the load.

While the use of a TBM relieves the need for large numbers of workers at increased pressure, if the pressure at the tunnel face is greater than behind the chamber a caisson system is sometimes formed at the cutting head this allows workers to go to the front of the TBM for inspection, maintenance and repair if this needs to be done under pressure the workers need to be medically cleared for work under pressure like divers underwater and to be trained in the operation of the locks.

Shields

Modern TBMs typically have an integrated shield. The choice of a single or double shielded TBM depends on the type of rock strata and the excavation speed required.

Double shielded TBMs are normally used in unstable rock strata, or where a high rate of advancement is required. Single shielded TBMs, which are less expensive, are more suitable to hard rock strata.

Excavation Works

Elements of risk exposure during excavation works are several. The most important ones are:

- submersion by water;
- fire and explosion;
- difficulties due to geotechnical external factors :
- damages due to tunnel collapse or detachment of rocks
- damages due to unexpected geological conditions;
- difficulties due to an inappropriate choice of the machine;
- difficulties due to the inexperience of the operator;
- difficulties due to the choice of the tunnel alignment;
- difficulties due to machinery breakdown,
- Breakthrough location.