

## **TUNNELS AND TUNNELING OPERATIONS: INTRODUCTION TO OLD AND NEW ERA**

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**Abstract:** *Tunnels are very important structures which are being used in various construction; like in road, railway for defence purpose and laying of pipelines etc. Tunnels have different shapes on the basis of their uses and the ground conditions and the availability of materials. All tunnels have various degrees of complexity depending on function and safety needs or the code requirements at the time of construction, but most tunnels employ one or many functional systems, such as lighting, ventilation, drainage, fire detectors and alarms, fire suppression, communications and traffic control. With the limited access and confined conditions within a tunnel; the operation, maintenance and inspection of a tunnel must be thoroughly regimented to provide an adequate level of safety for the traveling public. Construction of different types of tunnels include some vary basic operations or steps which are to be followed in sequence in order to built or to construct a tunnel. This are called basic tunneling operations. This tunneling operations may differ in comparision to older times and this modern time. This paper provides information on tunnels and various tunneling operations involved to make tunnel and also provide information related to old methods of tunneling and new methods of tunneling using ultramodern technology. Some case studies are also there related to the modern technology used tunnel construction.*

**Keywords:** Tunnels, Tunneling operations, TBM (Tunneling boaring machine), Mordern tunnelling operations.

### **I. INTRODUCTION**

#### **A. Definition**

Tunnel is an artificial underground passage, especially one built through a hill or under a building, road, or river (shown in figure 1 for railway tunnel). Tunnels are not only structures constructed of concrete, steel, masonry, and timber (to a very limited degree) or bored in rock, but also use numerous functional systems to perform roles for the tunnels to function properly.



**Figure 1: Railway tunnel (Source : <http://www.aecom.com/> )**

To construct any tunnel through river or through a hill, or a underground tunnel, There are certain operation or steps which are to be followed or to be performed, which are called various tunneling operations.

#### *B. Overview*

There are different types of tunnels according to their sizes like circular, rectangular, horseshoe, and oval/egg etc. The different shapes typically relate to the method of construction and the ground conditions in which they were constructed. Some tunnels may be constructed using combinations of these types due to different soil conditions along the length of the tunnel.

There are certain operation or steps which are to be followed or to be performed, which are called various tunneling operations shown in figure 2.

There are certain common operations which are performed generally like.....

1. Digging of shafts at the both end of tunnel
2. Horizontal operations at tunnel level (with the help of TBM machines or manually or by any conventional method.)
3. Lining of tunnel walls
4. Final works and Finishing works.



**Figure 2: Tunneling operations (Source : <http://www.gulftunneling.com/> )**

Except these stages or operations there are some other sub operations which are necessary to do like to suction water and other waste out of tunnel, certain safety operations...etc.

This tunneling operation may differ according to type of tunnel, method of tunneling, type of soil conditions, availability of equipment and labors. Tunneling operations are very lengthy and time consuming in past times, but nowadays with the availability of the all modern instruments it is possible to do all the tunneling operations with speed and accuracy.

### *C. Necessity of tunnels*

Economics of tunneling is a broad question and in general depends the relative cost of open cut Vs. tunneling. Generally when depth of cut is over 18 m, tunneling is advisable. From view point of economy and traffic safety, the tunneling operation is desirable under the following conditions.....

1. To allow rapid and unobstructed transport facilities in big the congested cities.
2. To avoid acquisition of valuable land.
3. To avoid long circuitous routes around a mountain or spur.
4. To avoid sliding of open cut sides in softer soils.
5. To connect two terminal stations separated by mountain.
6. To divert water for generation of power.

7. To carry public utility services like oil, gas, water etc. across the stream or a mountain.
8. To avoid the steep gradients in mountains and thereby maintain a high speed.
9. When the provision of the bridge over the river is costlier and inconvenient.
10. It is preferred on routes of strategic importance because a tunnel is hidden in ground.
11. To save the maintenance cost which is generally lesser for tunnel compared to a bridge and an open cut.

## **II. HISTORY / SCENARIO (PAST-PRESENT-FUTURE)**

In past times, to make tunnels through hill or to make underground tunnel was very lengthy and time consuming operation. And it was also include large number of labor force. In past time to make tunnel, some conventional methods were used like cut and cover method.

All the tunneling operations were to be done manually, no automatic machines or special techniques was available. Due to this the risk coefficient of all over tunnel project will increase and this also include some serious problems like water and dust handling. Some times hazardous accidents was occurred during past tunneling operations. To make tunnel in past time is very lengthy and time consuming operation and it was very uncertain due to lack of proper instruments and techniques.

Here are some construction methods.....

### **a) Cut and Cover**

This method involves excavating an open trench in which the tunnel is constructed to the design finish elevation and subsequently covered with various compacted earthen materials and soils. Certain variations of this method include using piles and lagging, tie back anchors or slurry wall systems to construct the walls of a cut and cover tunnel.

### **b) Shield Driven**

This method involves pushing a shield into the soft ground ahead. The material inside the shield is removed and a lining system is constructed before the shield is advanced further.

### **c) Bored**

This method refers to using a mechanical Tunnel Boring Machine (TBM) in which the full face of the tunnel cross section is excavated at one time using a variety of cutting tools that

depend on ground conditions (soft ground or rock). The TBM is designed to support the adjacent soil until temporary (and subsequently permanent) linings are installed.

d) Drill and Blast

An alternative to using a TBM in rock situations would be to manually drill and blast the rock and remove it using conventional conveyor techniques. This method was commonly used for older tunnels and is still used when it is determined cost effective or in difficult ground conditions.

e) Immersed Tube

When a canal, channel, river, etc., needs to be crossed, this method is often used. A trench is dug in the riverbed and prefabricated tunnel segments are made water tight and sunken into position in the trench where they are connected to the other segments. Afterward, the tunnel segments may be covered with earth to cover to fill the remaining voids around the tunnel segments in the trench and protect the tunnel from the water-borne traffic, e.g., ships, barges, and boats.

f) Sequential Excavation Method (SEM)

Soil in certain tunnels may have sufficient strength such that excavation of the soil face by equipment in small increments is possible without direct support. This excavation method is called the sequential excavation method. Once excavated, the soil face is then supported using shotcrete and the excavation is continued for the next segment. The cohesion of the rock or soil can be increased by injecting grouts into the ground prior to excavation of that segment.

g) Jacked Tunnels

The method of jacking a large tunnel underneath certain obstructions (highways, buildings, rail lines, etc.) that prohibit the use of typical cut-and-cover techniques for shallow tunnels has been used successfully in recent years. This method is considered when the obstruction cannot be moved or temporarily disturbed. First jacking pits are constructed. Then tunnel sections are constructed in the jacking pit and forced by large hydraulic jacks into the soft ground, which is systematically removed in front of the encroaching tunnel section.

Sometimes if the soil above the proposed tunnel is poor then it is stabilized through various means such as grouting or freezing.

In present time, tunneling operation is done with the help of modern instruments and modern techniques. Due to this tunneling operations become easier and quick as compare to past times. Modern machinery and GPS systems are used to navigate the hole project.

h) Using TBM :

TBM (tunnel borings machine) is one of the very very important machine for making of tunnel in present time. It can make tunnel through any type of soil conditions and even through rocks also.

A **tunnel boring machine (TBM)** also known as a "mole", is a machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata. They can bore through anything from hard rock to sand.

Tunnel diameters can range from a meter (done with micro-TBMs) to 19.25 m to date. Tunnels of less than a meter or so in diameter are typically done using trenchless construction methods or horizontal directional drilling rather than TBMs. Tunnel boring machines are used as an alternative to drilling and blasting (D&B) methods in rock and conventional "hand mining" in soil. TBMs have the advantages of limiting the disturbance to the surrounding ground and producing a smooth tunnel wall. This significantly reduces the cost of lining the tunnel, and makes them suitable to use in heavily urbanized areas.

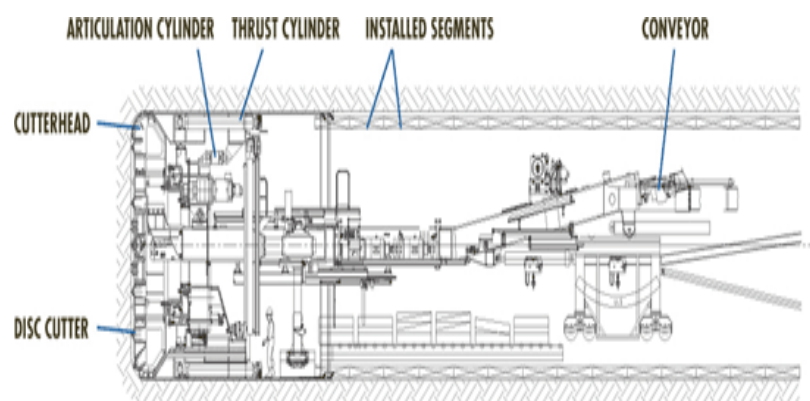


**Figure 3: TBM; Tunneling boring machine**  
(Source : <http://www.londonreconnections.com/> )



The major disadvantage is the upfront cost. TBMs are expensive to construct, and can be difficult to transport. However, as modern tunnels become longer, the cost of tunnel boring machines versus drill and blast is actually less-this is because tunneling with TBMs is much more efficient and results in a shorter project.

Behind all types of tunnel boring machines, inside the finished part of the tunnel, are trailing support decks known as the back-up system. Support mechanisms located on the back-up can include: conveyors or other systems for muck removal, slurry pipelines if applicable, control rooms, electrical systems, dust removal, ventilation and mechanisms for transport of pre-cast segments.



**Figure 4: Elements of TBM**

(Source : <http://www.fhwa.dot.gov/bridge/tunnel>)

Above figure 3 shows the ultra modern TBM (tunnel boring machine) which is very helpful in this time. Figure 4 shows some parts of TBM like conveyor, cutter, thrust cylinders etc.

### **III. MORDERN TUNNELLING OPERATIONS**

#### **1. Install TBM to proper place**

In this , first shaft is made to the ground where TBM have to install. Than after TBM is installed at proper site under the ground with the help of ultra modern instruments and man power.

#### **2. Cutting and mud removal operations of TBM**

After installing TBM at proper place, it starts working and cutting and drilling operation started with the help of cutter blades of TBM.

### 3. Forward horizontal operations

TBM will be forwarded using jacks, which are mechanically working or hydrological working operation. This jacks helps TBM to move forward and make tunneling operation faster.

### 4. Lining operations

Lining is done mechanically with the help of various robots. This lining give support to the tunnel walls and avoid sliding and dangerous accidents.

### 5. Finishing works/operations

After completion of the whole tunnel , finishing work and other facilities will be included in to tunnel like electrification , ventilation etc.

## **IV. ADVANTAGES AND DISADVANTAGES**

### *A. Advantages*

1. Tunnels are more economical than open cuts beyond 18 m depth.
2. Tunnels avoid disturbing or interfering with surface life and traffic during construction.
3. For carrying public utilities like water , gas , railway lines , roads across a stream or a mountain , tunnels are cheaper than bridges or open cut.
4. Tunnels avoid dangerous open cuts adjacent to the structure.
5. Tunnels avoid traffic conjunction and provide rapid transportation in crowded cities.
6. Tunnels connect two terminals stations by shortest route.
7. Tunnels carry water to generate power.
8. If tunnels are provided with easy gradients , the cost of hauling is decreased.
9. Tunnels provide protection from bombing during aerial warfare.
10. Tunnels avoid acquisition of costly land property.
11. Tunnels provide protection against weathering actions like wind , rain , sun etc.



## *B. Disadvantages*

1. The initial cost of construction of a tunnel is high as compared to an open cut.
2. Construction of tunnels requires long time in completing as compared to open cut.
3. Specialized equipment and methods are required for execution of the work.
4. It is necessary to have skilled labors and technical supervision of high order for construction of the tunnels.

## V. CASE STUDIES OF TUNNELS AND TUNNELING OPERATIONS

### *A. Case Study – I [gotthard base tunnel]*

The **Gotthard Base Tunnel** (GBT) (shown in figure 5) is a railway tunnel in the heart of the Swiss Alps expected to open on June 2, 2016. With a route length of 57 km (35.4 mi) and a total of 151.84 km (94.3 mi) of tunnels, shafts and passages, it is the world's longest rail tunnel, surpassing the Seikan Tunnel in Japan.

The project consists of two single-track tunnels. It is part of the Alp Transit project, also known as the New Railway Link through the Alps (NRLA), which includes the Lötschberg Base Tunnel between the cantons of Bern and Valais and the under construction Ceneri Base Tunnel (scheduled to open late 2019) to the south. It bypasses the Gotthardbahn, a winding mountain route opened in 1882 across the Saint-Gotthard Massif, which is now operating at capacity, and establishes a direct route usable by high-speed rail and heavy freight trains.



**Figure 5: Gotthard base tunnel**  
(Source : <http://archinect.com/firms/project>)

## Specifications of GOTTHARD BASE TUNNEL

### **Length:**

**Western tunnel:** 56.978 km (35.404 mi)

**Eastern tunnel:** 57.091 km (35.475 mi)

**Total length of all tunnels and shafts:** 151.84 km (94.35 mi)

**Diameter of each of the single-track tubes:** 8.83–9.58 m (29.0–31.4 ft)

**Distance between cross passage tunnels:** ca. 325 m (1,066 ft)

**Maximum overburden:** 2,500 m (8,200 ft)

**Start of construction:** 1993 (sounding drills), 1996 (preparations), 2003 (mechanical excavation)

**End of construction:** 2016

**Commissioning:** May 2016

**Total cost:** CHF 9.74 billion (as of October 2010) (US\$10.1 billion)

**Trains per day:** 200–250

**Electrification System:** 15 kV, 16.7 Hz

### *B. Case Study – 2 [drogden tunnel | underwater]*

The Öresund or Øresund Bridge (Danish: *Øresundsbroen*, Swedish: *Öresundsbron*, joint hybrid name: *Øresundsbron*) is a double-track railway and dual carriageway bridge across the Oresund strait between Scania (southernmost Sweden) and Denmark. The bridge runs nearly 8 kilometers (5 miles) from the Swedish coast to the artificial island of Peberholm, which lies in the middle of the strait.

The crossing of the strait is completed by a 4 km (2.5-mile) underwater tunnel, called the Drogden Tunnel, from Peberholm to the Danish island of Amager. The term Øresund Bridge often includes this tunnel.(shown in figure 6)

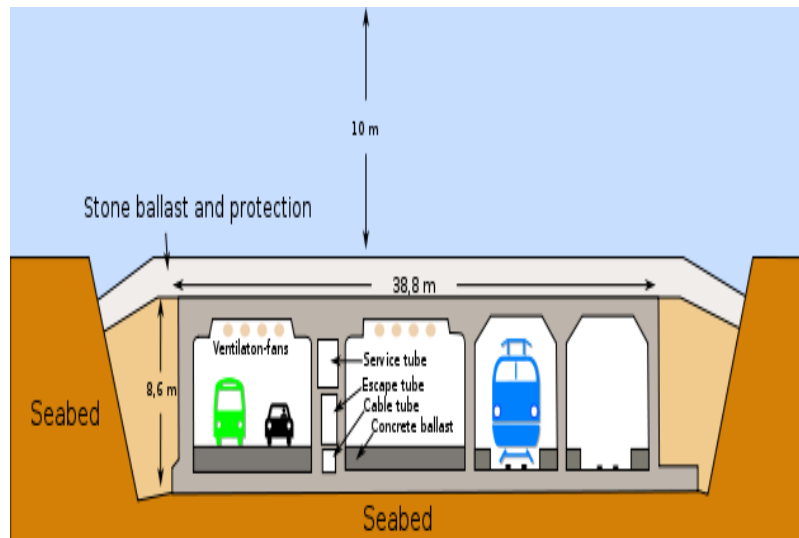


**Figure 6: Oresund tunnel**  
(Source : <http://da.wikipedia.org/>)

The 4,050 m (13,287 ft) long tunnel comprises a 3,510 m (11,516 ft) undersea tube tunnel plus 270 m (886 ft) entry tunnels at each end. The tube tunnel is made from 20 prefabricated reinforced concrete segments – the most massive in the world at 55,000 tones each – interconnected in a trench dug in the seabed. Two tubes in the tunnel carry railway tracks; two more carry roads while a small fifth tube is provided for emergencies. The tubes are arranged side by side.

The tunnel construction was tendered in 1994 as a design and construct contract, the conceptual design being carried out by the Oresund link consultants. . The 175 m tunnel elements are composed of eight 7000t segments, match cast in single concrete pours, and joined by temporary prestressing.

The segment are fabricated under factory conditions in two production lines located above sea level, obviating the need for time consuming excavation and dewatering of a conventional casting basin. The completed elements are launched and lowered to sea level by means of a lock system and then towed to the tunnel site for immersion. (shown in figure 7)



**Figure 7: cross-section of Oresund tunnel**  
(Source : <http://en.wikipedia.org>.)

## VI. CONCLUSION

From the literature review and case studies, following conclusion are drawn:

- 1) It can be said that the tunnels are very important construction work in the context of economy, facility, modern technology and comfort.
- 2) Modern TBM machines are very useful for the construction of tunnels as per specifications and modern needs and in a speedy manner. By using them underwater tunnel constructions can also be done.
- 3) Tunnels are very useful in various areas like roads and railway construction and except it , it is very useful for special purpose projects like for the use of military operations.
- 4) Nowadays construction of tunnels are easy as compared to the construction of tunnels in past times without using any modern techniques and machineries.

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