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Tunnelling Methods – Kolkata Under Ground Metro, India – Case Study

Bommakanti VKL Kumar, Ph.D., Civil Engg

NMDC Steel Limited, Nagarnar, Jagdalpur, Chhattisgarh, India. E-mail: bvklalitkumar(at)rediffmail.com

Abstract **- In this paper, importance of tunneling and their methods are discussed. Most importantly, Metro projects are becoming current trends in India and one of the popular underground Metro which is existing in Kolkata with latest under water tunnel project is presented in this paper. It is an important project for Civil Engineers with some project highlights are given for upcoming generation. As underwater tunnel is first of its kind and gaining popularity.**

Keywords: Tunnelling, East West Metro Kolkata, Tunnel Boring Machine.

I. INTRODUCTION

Tunnels and their methods are not new, but new technologies are helping in excavation through tough terrains above and below water bodies. Tunnels play important role in transportation and movement of materials and people. In India, various types of tunnels can be found in Ajanta and Elora Caves, their creation is till date mystery.

In western countries, tunnels were made for public transportation, sewage, water supply and they were constructed with old and new technology.

Tunnel construction refers to the creation of an underground passage that is situated beneath the surface of the earth or beneath water bodies or through hilly regions. Various techniques and specifics related to tunnel construction are examined. Generally, the process of constructing a tunnel incurs significant costs; however, it offers time savings and enhanced convenience. Substantial excavation of soil or rock is required for the establishment of a tunnel. The advent of modern machinery has simplified the processes of excavation and backfilling. Tunnels serve multiple purposes, including roadways, railways, and waterways. In numerous urban areas, underground metro rail systems operate within tunnels.

1.1 Methods of Tunnelling

Techniques for Tunnel Construction A range of construction methods has been established for the development of tunnels, which are outlined as follows:

- Cut and cover technique
- Bored tunnel technique
- Clay kicking technique
- Shaft construction method
- Pipe jacking technique
- Box jacking technique
- Underwater tunnel construction

a) The Cut and Cover Method for Tunnel Construction. The cut and cover method is primarily employed for the construction of shallow tunnels. This technique involves excavating a trench in the ground, which is subsequently covered with a supportive structure capable of bearing loads. There are two primary excavation approaches: the bottom-up method, where the tunnel is dug from beneath the surface with the aid of ground support, and the top-down method, which involves first constructing side support walls using techniques such as slurry walling or contiguous bored piling. After establishing the walls, a roof is placed on top, followed by excavation, and finally, the base slab is laid. This method is commonly utilized for the construction of underground metro rail stations.

b) Bored Tunnel Method The bored tunnel method represents a contemporary approach to tunnel construction. This technique utilizes tunnel boring machines (TBMs) that operate automatically, streamlining the tunneling process. It is a faster and more efficient method, particularly suitable for areas with high traffic. TBMs come in various types, each designed for specific ground conditions, and can operate effectively even in challenging environments, such as below the water table. A specialized pressurized compartment is incorporated for TBM operations in such conditions, and access for workers is restricted to maintenance tasks only. While TBMs enhance efficiency, their significant weight poses challenges for transportation, making it a more expensive option.

c) Shaft Method: Using shaft method, the tunnel is built farther below the surface of the earth. The shaft constructed to the depth needed for a tunnel. Similar to a well with concrete walls, a shaft is a permanent construction. TBMs are used to excavate tunnels to the necessary depth. Both the tunnel's entrance and exit have shafts. If the tunnel is too long, there are also

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intermediate shafts available. These shafts can be utilized as emergency exits and for ventilation after construction is complete.

d) Pipe Jacking Method: The pipe jacking method is used to build tunnels beneath existing infrastructure, such as railroads and roads. Using pipe jacking technique, hydraulic jacks are used to drive specially designed pipes underground. Tunnels may have a maximum diameter of 3.2 meters.

e) The Box Jacking Technique: Similar to pipe jacking, box jacking involves driving specially made boxes into the ground in place of pipes. On the front side of the box is a cutting head. The box contains the collected excavated matter.

f) Box jacks can be used to excavate larger tunnels up to 20 meters in length.

g) Construction of Underwater Tunnels.

A structure constructed below the surface of the water to provide passage is called an underwater tunnel. An underwater tunnel is a wise option if building a bridge is not feasible.

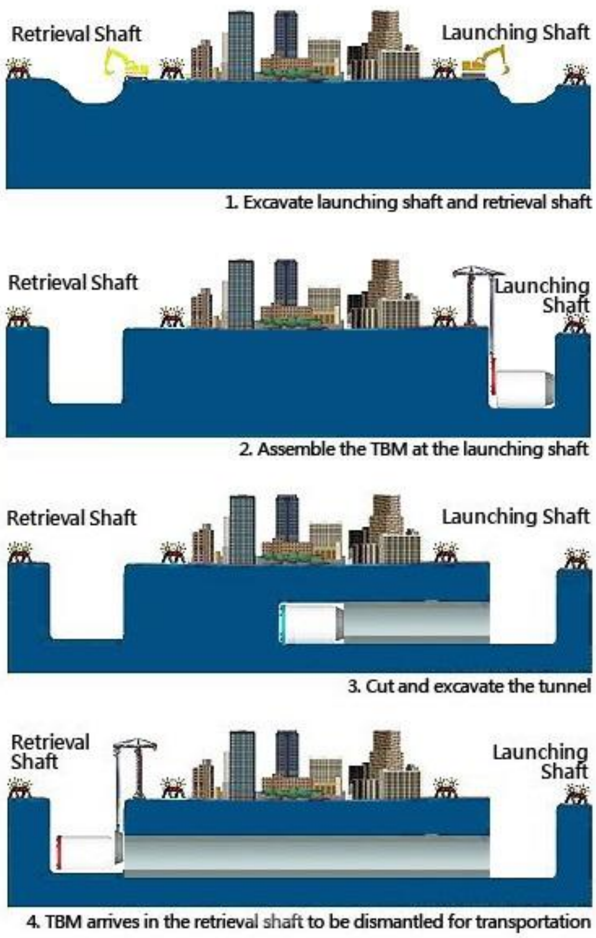

Figure 1: Shaft and TBM erection and movement (Source Railway Engineering)

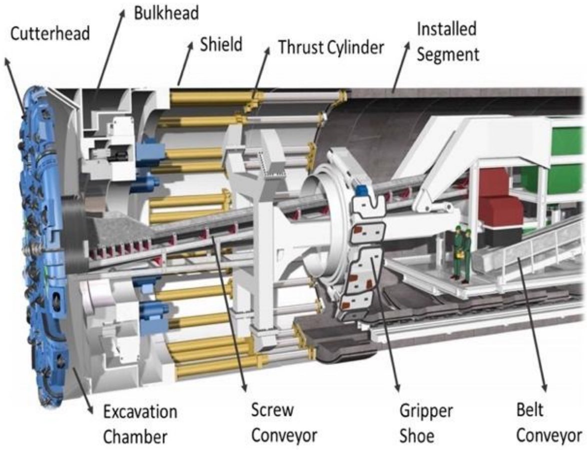

Figure 2: Tunnel Boring Machine (Source: TBM)

1.2 Steps involved in Construction of a Tunnel

As such Tunnelling is a highly specialized field requiring a blend of technical knowledge, field experience and engineering judgment.

It is important to conduct Geotechnical investigation to asses type of soils in the terrain. Collection of data from available maps of survey of India, boreholes and their samples, satellite imageries and availability of lands and encroachments. Preliminary geological field mapping, geophysical exploration arriving seismic refraction surveys, aerial photography and ground water data. Geological formations, such as folds, faults, lineaments.

Next step is to perform detailed topographical survey, subsurface investigations, detailed geological mapping, detailed hydrological survey and water table, structure and utility preconstruction survey. Details regarding conducting such boreholes are given in RDSO Guidelines, 2012.

1.3 Tunnel Alignment

It is important to maintain required alignment in construction of tunnel. Use of lasers in tunnel alignment has been considered appropriate method.

The tunnelling construction methodology must include tunnel alignment while considering longitudinal and transverse directions.

II. CASE STUDY – KOLKATA UNDER WATER METRO

2.1 Kolkata Metro

Construction for Kolkata Metro Line-1 was started in year 1972 and completed 3.40 km length between Esplanade and Netaji Bhavan opened in October 1984. This was the first

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metro system in India. Between 1984 and 1995, more sections opened up bringing its total length to 16.45 km.

After the success of the Delhi Metro's Phase 1, in mid 2000 the metro lines in Kolkata were extended further to 10.94 Km upto Kavi Subhash Station.

In 2009, construction began on Kolkata Metro's 14.67 km east-west Line-2 from Salt Lake Sector V to Howrah Maidan, a project that was earlier under the Ministry of Urban Development's belt but later transferred to the Ministry of Railways by the central government. The first section of that line opened on February 13, 2020. The final section (Howrah Maidan to Phoolbagan) completed and open for public in 2024.

2.2 Kolkata East west Metro Project – Soil Conditions

The East west Metro project of Kolkata runs 13 meter below the river Ganges and tunnels of diameter 6.1 meter and separated by a distance of 15m. The soil strata are soft clay deposited by the river with layers of clayey silt to silty clay. The alignment passes nearer to old heritage-buildings and protection of such buildings was considered as main criteria in assessment of Static and dynamic methods of finite element analysis were performed by Aniruddha Sengupta et al.

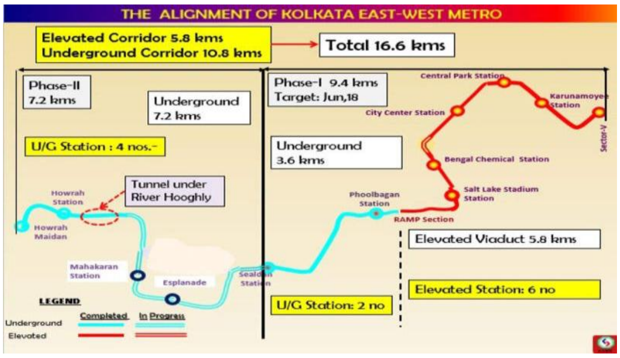

Figure 3: Route map of East-west Metro, Kolkata

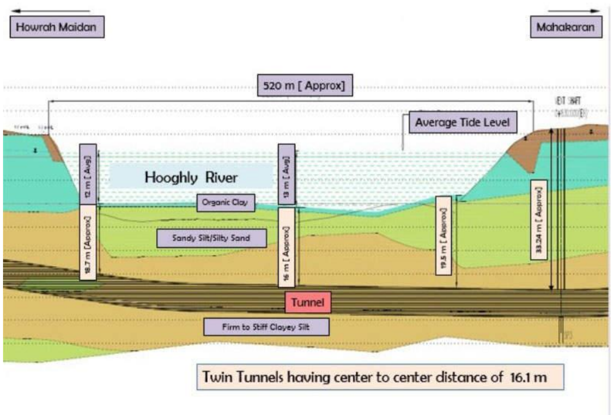

Figure 4: Tunnel cross section below river Hoogly

III. CONSTRUCTION DETAILS

The 10.8 km subterranean portion of the East-West Metro project in Kolkata, India, is known as the East-West Metro Underground Twin Tunnel project. There are two underground twin metro rail tunnels in this section, one heading east and one heading west.

The 16.6 km East-West Metro Corridor project is a metro rail line that is currently under construction that will link Howrah and Kolkata. The 5.8 km elevated portion of the corridor will be covered. The East-West Metro tunnel will be India's first underwater tunnel when it crosses the Hooghly river, which will require a 520-meter underwater section of the tunnel for about half a kilometre. The extra-dose tunnel crown will be 13 meters below the riverbed, and the underwater tunnel will be 13 meters below the water. Japan Bank for International Cooperation (JICA) is providing partial financial support to Kolkata Metro Rail Corporation (KMRCL) to carry out the project.

The Indian government authorized an updated cost estimate of Rs8,575Cr ($1.17bn) in October 2020.

The metro project's second phase, which covers the section between Sealdah station and Howrah Maidan, started construction in March 2016 and is presently in operation. December 2021 is when the underground tunnels are expected to be finished.

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The first underwater tunnel in India was designed and built. The tunnel will measure 6.1 meters in diameter outside and 5.55 meters inside. The center-to-center distance between the tunnels will be 16.1 meters.

Segments of reinforced concrete, each 275 mm thick, grade M50 are being used to construct the tunnel's inner walls. The circular lining of the tunnel's diameter will be completed by six of these segments. Pre-cast segments are produced using specialized molds that are imported from Korea.

To stop water from seeping into the tunnel and leaking, several safety precautions have been implemented. For the segments, fly ash and micro silica-based concrete mixes have been utilized to reduce water permeability.

A difficult grouting procedure was used to seal the segments, filling the space between them and the tunnel boring machine's shield (TBM).

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To fill in the gaps, a two-component grout mix consisting of a slurry of cement, water, bentonite, and sodium silicate is being used. Neoprene and hydrophilic auxiliary gaskets, manufactured in Germany, were installed on the liner segments. These gaskets expand in the presence of water to stop inflow through segmental joints.

Boring the twin underwater tunnels was one of the complex challenges of the project. German-made tunnel boring machines (TBMs), named Prerna and Rachna, were used for underground tunnelling.

The two underwater tunnels are boring. One of the project's more difficult tasks has been boring the underwater tunnels, which are primarily made of soft and stiff clay. Prerna and Rachna, two tunnel boring machines (TBMs) built in Germany, were used in the procedure.

The machines are appropriate for projects on unstable terrain or under structures that are susceptible to ground disturbances because they are equipped with earth pressure balancing (EPB) capabilities. During the boring process, they can withstand three times more atmospheric pressure. Each TBM has backup gantries that extend up to 100 meters, and it is 8.5 meters long and as tall as a two-story building. The six 1,010kVA generator sets will power the boring machines, which have over 35 additional auxiliary motors and five motors that are more powerful than 650 HP. To finish the 2.9 m of the tunnel, the TBMs will bore up to 15 m per day, excavating up to 500 m³ of earth.

The east and west bound tunnels were bored by the two TBMs in a record 66 days, from April to June 2017. The second tunnel crossed the river in June 2017, whereas the first one did so in May 2017.

Technologically speaking, the underwater tunnel construction is similar to the Eurostar high-speed rail service that runs through the Channel Tunnel between the United Kingdom and France.

In March 2021, the TBM S-616 Urvi was sent in to build the last section of the East-West Metro, which is located 17 meters below Sealdah station.

IV. PROJECT TIMELINES AND COMPLETION HURDLES

2010: Contract for building the underwater tunnel section from Central to Howrah Maidan awarded to Afcons. 2010-2015 There were realignment issues on account of shifting of project affected families. 2017 March first TBM completed boring under Hoogly river. Due to heritage buildings, permission was obtained from Archeological survey of India on June 2017 to construct tunnels near heritage buildings. Dec 2017 tunnelling commenced from Mahakaran station to esplanade. March 2018, Prerna, first TBM completed Howrah Maidan to Esplanade. Apr 2018, second TBM, Rachna had completed tunnel between Howrah Maidan to Esplanade. On June 2019, both TBMs, Rachna and Prerna were taken out from project site. May 2023, tunnelling East west metro was completed. March 2024, the prestigious project was inaugurated by PM of India and opened for public.

V. RESULTS AND DISCUSSIONS

Tunneling with Tunnel Boring machine is appropriate for soft and rock formation. However, TBM is very expensive and require shafts at start and end point of operations. Ans it is difficult in shipping to project sites. One of the case studies is presented here with some points considered here.

VI. CONCLUSION

Tunneling has become widely accepted procedure for making passages for roads, railways, sewers and other utility requirements. Tunnels make shortest distances between long routes. However, technical feasibility studies to be done before choosing tunnels as they are expensive and difficult in driving them in urban areas causing displacement of residents. Secondly, it is important to understand subsurface disturbances and seismic histories of project site of the proposed region.

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