International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Special Issue – NCITTATME'21

Tunnel Boring Machine (TBM) in Underground Metro Projects

Mr. Abhishek Sagar Chougule, Student of Project & Construction Management Department, MIT College of Management, Pune, India, abhishekchougule8055@gmail.com

Prof. Shankar Banerjee, Assistant Professor-MITCOM-PCM Department, MIT-ADT University, Pune, India, shankar.banerjee@mituniversity.edu.in

Abstract - **A full-face rock tunnel boring machine (TBM) is a kind of large-scale construction machinery specially used for excavation of underground passage works. It is used widely in subway, railway, highway, municipal, and hydropower projects. : Because of their demonstrated capabilities in attaining high rates of advance in civil tunnel construction, the hard rock mining industry has always shown a major interest in the use of TBMs for mine development, primarily for development of entries, as well as ventilation, haulage and production drifts. The successful application of TBM technology to mining depends on the selection of the most suitable equipment and cutting tools for the rock and ground conditions to be encountered. In addition to geotechnical investigations and required rock testing, cutter head design optimization is an integral part of the machine selection to ensure a successful application of the machines in a specific underground mine environment. This paper presents and discusses selected case histories of TBM applications in mining, the lessons learned, the process of laboratory testing together with machine selection and performance estimation.**

Keywords — Construction Automation, Earth Pressure Balancing Method (EPB), Metro Projects, Tunneling, Tunnel Boring Machine (TBM), Urban Infrastructure, Underground Metro.

I. INTRODUCTION

EARTH PRESSURE BALANCE (EPB) TBM:

This is a motorized burrowing technique in which ruin is conceded into the passage exhausting machine (TBM) through a screw transport course of action which permits the pressing factor at the substance of the TBM to stay adjusted without the utilization of slurry.

Figure 1. Mutha – Tunnel Boring Machine

DETAILS OF TBM:

TBM Diameter:	6.610 M
Manufacturer:	Terratec, Tasmania, Australia.
Type of TBM:	Earth Pressure Balance(EPB)
TBM Cutter Head Diameter:	6.650 M (54T)
Shield Outer Diameter:	6.610 M (450T)
Shield Inner Diameter:	6.410 M
Cutter Head + Shield Length:	10.115 M
Backup Length:	90 M
Overall Length of TBM: (Cutter Head + Shield + Backup)	100 M
No. of Shield Jack Cylinder:	16 sets (2in each set)
Unit Thrust Force:	2,500 KN
Total Thrust Force:	40,000 KN
Hard Rock Cutting Speed:	18-20 mm/min

Table 1. Details of TBM

It has the benefits of quick uncovering, top caliber, wellbeing, economy, natural assurance, and diminished work power. The shaper head framework is the center

 DOI : 10.35291/2454-9150.2021.0469

working piece of full-face rock TBM, what breaks the stone and supports the passage face. The TBM shaper head is a key part influencing driving execution and productivity. The assessment of burrowing execution is a significant reason for the plan of the shaper head. TBM burrowing productivity boundaries incorporate driving rate, development plan, shaper wear, and machine usage rate. Passage exhausting machine (TBM) is a machine that is utilized to uncover burrows. TBMs can drill through an assortment of ground conditions, from hard rock to sand. To build the passages, the TBMs will continuously fix each passage with bended solid sections as they burrow. The twin passages will include 56,000 individual solid sections.

Each TBM is furnished with a best in class route framework that will guarantee they burrow precisely along the passage arrangements. They are staffed and observed 24 hours every day, 7 days per week, and completely furnished with staff offices, including an office, kitchen and latrines. The Metro Tunnel Project will utilize blend safeguard TBMs – usually known as slurry TBMs – that are reason worked to suit the nearby ground conditions. When the TBM's shaper head drills through the ground, the exhumed material will be blended in with slurry and shipped back to the over the dumping yard.

II. Background

In the United States, the principal exhausting machine to have been fabricated was utilized in 1853 during the development of the Hoosac Tunnel in northwest Massachusetts. Made of cast iron, it was known as Wilson's Patented Stone-Cutting Machine, after innovator Charles Wilson. It bored 10 feet into the stone prior to separating.

III. Working of TBM

- A TBM is shaped like a tube.
- At the front is a rotating disk with cutting teeth that can shear through rock.
- The pulverized rock falls to a conveyor belt that carries it to the back of the TBM.
- Behind the cutting wheel, there is a chamber and inside it there is a set of 16nos. hydraulic jacks which push the TBM forward.
- Behind the shield, at the finished part of the tunnel several support mechanisms such as control rooms, rails for muck removal, slurry pipelines etc., can be set up.
- There is also the ability to insert Segments to line the interior of the tunnel.

TUNNEL SERVICES:

- **Ventilation Duct:** 600mm Dia. To provide fresh air- keeping 10m away from TBM.

RIGHT SIDE OF THE TUNNEL

- High Voltage Cable
- Low Voltage Cables
- Communication Cables

LEFT SIDE OF THE TUNNEL

- Hydraulic Hose
- Service Pipes :
  1. Water Return Pipe = 4 inches
  2. Water Supply Pipe = 4 inches
  3. Grout A-Pipe = 2 inches
  4. Sodium Silicate = 1.5 inches
  5. De-watering Pipe = 4 inches
- Walkway – Connected to the pre-installed walkway of the Backup Gantries.
- Single Track System – till backup gantries goes inside the bore tunnel.

TBM OPERATING SYSTEM:

- TBM Guidance System = ROBOTEC
- TBM Position & Posture is displayed graphically with Auto Survey Results.

Figure 2. TBM Opertaing System

PARTS OF TBM:

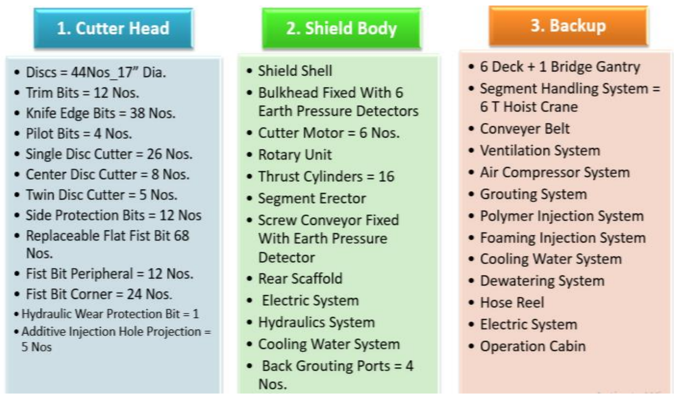

Chart 1. TBM Parts

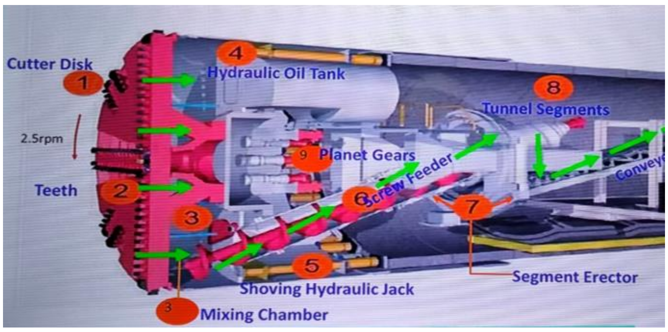

Figure 3. Main Parts of TBM

 DOI : 10.35291/2454-9150.2021.0469

ACTIVITY FOR TBM EXCAVATION:

1.	TBM Excavation Diameter	6.650 M
2.	Segment Length/ Ring	1.4 M
3.	Muck Volume/Ring(Theory)	48.63 cum
4.	Swelling Factor	1.55
5.	Muck Volume/Ring (Loose)	75 cum
6.	Muck Skip Volume	12 cum
7.	No. of Muck Skip 1 Train	6.3 nos.
8.	Capacity of Muck I Train	75 cum
9.	Crane Lifting Depth (for Tipping Muck)	15 M
10.	Crane Traveling Distance (for Tipping Muck)	40 M

Table 2. Activities for TBM Excavation

IV. METHODOLOGY

1. Excavation of up line tunnel will be first commenced & then down line.
2. All the TBM parts & back up gantries will be lowered for main drive operation.
3. For access, locomotive movement railing is done at the bottom of the shaft.
4. All 7 backup gantries, Shaft and other accessories will be assembled & connected inside the Cut & Cover Tunnel.

Figure 4. Lowering of TBM & Locomotive

5. Connection of all cables, hydraulic hoses to the backup gantries is done.
6. Grout pipes are connected from grout plant to back up gantries and TBM.

Figure 5. TBM Backup System

7. TBM drive test run is done & then chainage of wall shaft is started.
8. Temporary/ Dummy Rings 9nos. are erected with the help of thrust/reaction frame.
9. Reaction frame is also removed using 100T crawler Crane.
10. Then Extension of platform & crossing is done as per requirement.

Figure 6. Ring Building & Dummy Rings

ERECTION OF TEMPORARY 9 RINGS:

1. Thrust/reaction frame is erected, temporary rail track & temporary working platform is erected within reaction frame at bottom of shaft.
2. Segments are lowered down by using gantry crane on to the flat/segment car of Locomotive 27T.
3. Segments are transported to the back of TBM i.e. 1st back up gantry and then to segment feeder.
4. T1 ring building is done with the help of Thrust/reaction frame.

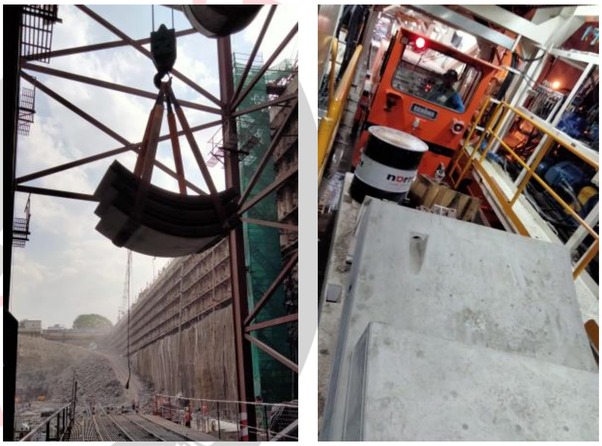

Figure 7. Segment Lowering & Transportation

5. The 1st Temporary ring will bear directly on thrust frame with the help of modified bolt to position to hold the ring in circular shape.
6. Additional 100mm channels will be welded at the crown, shoulder, Knee, invert locations to maintain circularity of the first temporary ring built.
7. By shoving TBM forward and 2nd Ring building is done.
8. A 16mm wire rope is used to hoop around the middle rings.
9. Timber / Steel wedge & Bracing required to hold the ring on position.
10. Same process is Repeated until ring no. 9
11. Anti-wear foam is injected once cutter head reaches to rock for excavation.
12. All Excavated Material reaches to Muck Car with the

 DOI : 10.35291/2454-9150.2021.0469

help of Conveyer Belt.

13. Muck car is lifted & disposed at Dumping Yard with help of Gantry Crane.
14. Then Permanent ring building is started from P1, P2, P3,.. Onwards.

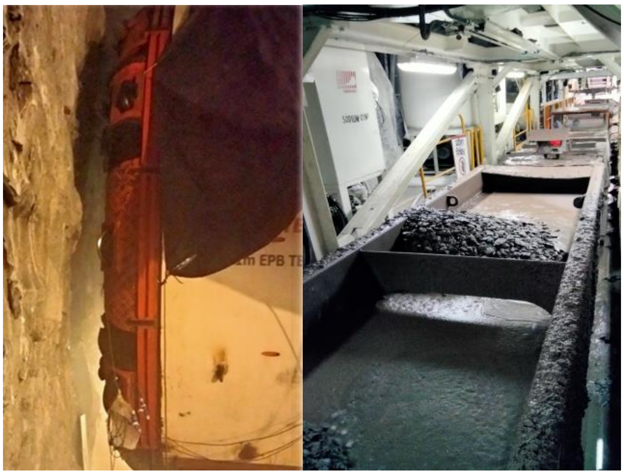

Figure8. Excavation, Muck Transporting & Disposing

- Swarget station to Mandai station = 1176m
- No. of rings required for Tunneling = 844

Figure 9. Downline Tunnel at Swarget Station

V. Results

TUNNEL TIME CYCLE:

Sr. No	Activity Production Time	Time Consumed (min)	Remark
1.	Train toward TBM	1.20	
2.	Segment unloading to segment feeder & train move to Discharge Point	15	
3.	Excavation	70.00	
4.	Check Segment Gap clearance after excavation	10	
5.	Segment erection	45	
6.	Train backward Launching Shaft	1.71	
7.	Muck Tipping	43	
8.	Unloading segment to Segment car	15	One ring of segment at bottom shaft
9.	Unloading Tunnel Material to flat car	10 **210.91 mins.**	Tunnel material stock at bottom shaft
	Ideal time		
1.	Segment Unload form yard to bottom Shaft	9	
2.	Tunnel Materials unload from Yard to bottom shaft	5	
3.	Rail Extension	20	
4.	Extension	15	
		49 mins	

Table 3. TBM Cycle Time Analysis

1	TBM Excavation Speed	20 mm/min
2	Loco Speed (Train towards TBM)	10 km/hr
3	Loco Speed (Train towards Launching Shaft)	7 km/hr
4	Gantry Crane Hoisting Speed	15mm/min
5	Gantry Crone Traveling Speed	30 mm/min
6	Gantry Crone Traveling Speed	6.3 mm/min
7	Segment Crane Hoisting Speed	28 mm/min

Table 4. Activity for TBM Excavation

ADVANTAGES:

- Allows delicate, wet, or insecure ground to be burrowed with a speed and security not already conceivable.

- Limits ground settlement and produces a smooth passage divider. This altogether diminishes the expense of covering the passage, and makes it appropriate to use in vigorously urbanized regions.

DISADVANTAGES:

- The significant detriment is the forthright capital expense. TBMs are costly to build, hard to ship, require huge reinforcement frameworks Backup System and Power.

VI. Conclusion

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

 DOI : 10.35291/2454-9150.2021.0469

ISSN : 2454-9150 Special Issue – NCITTATME'21

References

[1] Alexander, C. 1999. Development of Stillwater Mining Company's East Boulder Project Using Tunnel Boring Technology. SME Annual Meeting. Denver CO, USA: 1-8

[2] Janbaz, S., 2017. "Development of a Production Estimation Model for Tunnel Boring Machines (TBMs)." A Doctoral Dissertation, The University of Texas at Arlington, TX, 2017.

[3] Allum, R. & VanDerPas, E. 1995. TBM Technology in a Deep Underground Copper Mine. Rapid Excavation and Tunneling Conference: 129-143

[4] Bruland, A., Nilsen, B. 1995. Tunneling Performance Estimation based on Drillability Testing. Proc. 8th ISRM Congress on Rock Mechanics. Vol. I: 123-126

[5] Cigla, M. & Ozdemir, L. 2000. Computer Modeling For Improved Production of Mechanical Excavators. SME Annual Meeting. Salt Lake City UT, USA

[6] Farrokh, E., 2013. Study of utilization and advance rate of hard rock TBMs, Ph.D. thesis, The Pennsylvania State University.

[7] Jalalediny Korky, S., Najafi, M., Malek Mohammadi, M., Ashoori, T., Tabesh, A., (2017). "An Analysis of Soil Hauling Operations for Tunneling and Pipeline Installation." ASCE Pipelines 2017.

 DOI : 10.35291/2454-9150.2021.0469