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New Austrian Tunnelling Method (NATM) in Urban Metro Projects

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Abstract: ***Tunnels have contend a crucial role among the evolution and Sustenance of man-kind through the ages. History has seen the evolution of tunneling beginning with cave formation, for water management, below ground transportation, extraction and for warfare functions. Initially hand dug with crude tools like chisels, Hammers, spades and shovels, the engineering tunneling technology has seen progress in leaps and bounds. The ever increasing wants of the modern humanity have driven the tunneling technology to its pinnacle. Tunneling in Urban areas is more challenging due to presence of old buildings, rivers, bridges, monuments, historical places, high rise construction. Usually this can be often being accomplished through fast advancements in terms of earth science and hydro-geological engineering, tunnel style, capacity, construction ways and speed and maintenance throughout operations. Safety throughout construction and operations is obtaining integrated altogether aspects through acutely aware and educated selections. In most of the cases tunnel construction is expensive however it saves time and provides comfort. Massive excavation of soil or rock etc. is vital for a tunnel construction. With the availability of recent instrumentality, excavation and backfilling has become easier.***

Keywords: Tunneling, New Austrian Tunneling Method (NATM), Urban Infrastructure, Metro, Advance Construction Technology.

I. INTRODUCTION

Tunnelling in urban setting presents variety of unique challenges. A typical urban setting will include the presence of major roadways, potential shallow ground cover, soft ground conditions and potentially mixed ground, existing or abandoned foundations and buried structures, and enormous intricate networks of wet and dry utilities. Additionally, space constraints in urban settings magnify the challenge of implementing tunnelling in such a fashion on avoid inducing displacements damaging to adjacent facilities, structures and utilities.

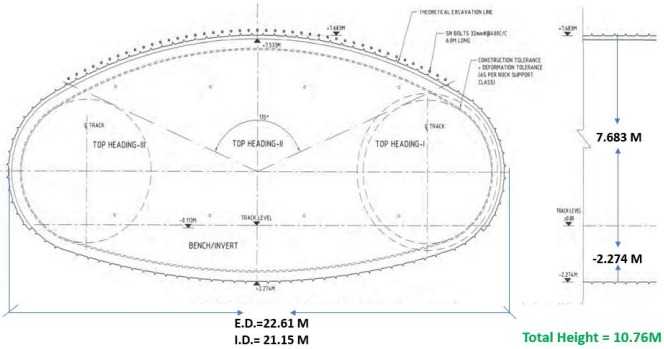

Figure NATM Profile

A. Total Length of NATM Tunnel = 141.29M

The use of cut-and-cover construction will further impact traffic, require utility relocation and/or support in situ, affect businesses and expose the general public to noise, dust and vibration and impact the people quality of life during construction.

However, these challenges are often addressed with carefully designed tunnelling method, the utilization of the newest technologies in tunnelling, the utilization of prudent excavation and support sequencing, implementation of ground improvement and a strong instrumentation and monitor program which will identify potential issues early and implement corrective actions. With a risk mitigated approach during the planning phase, and therefore the use of the newest TBM technologies, tunnelling has proven successful in complex urban settings..

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II. BACKGROUND

The term New Austrian Tunnelling Method Popularly Known as NATM got its name from Salzburg (Austria). It was first used by Mr. Rabcewicz in 1962. It got world wise recognition in1964. This method has been evolved as a result of experience gained in Austrian Alpine tunnelling condition. The first use of NATM in soft ground tunnelling is done in Frankfurt metro in 1969. The basic aim of NATM is for getting stable and economic tunnel support systems. This method has been very useful in complex diversified geological condition where forecasting of the rock mass is difficult due to rapidly changing geology.

III.METHODOLOGY

NATM has become the tactic of choice for tunneling in urban areas to construct complex underground structures like metro stations, multi-track metro lines, rail crossovers, short road tunnels and underground road ramps so as to avoid cut-and-cover construction with its impacts on streets, utilities, traffic, and businesses and therefore the public.

Under these conditions and where complex and challenging ground conditions exist, underground construction requires a versatile design which will be executed effectively and safely, while minimizing impacts to existing structures. This specifically includes tunneling in running and flowing ground, tunneling under high water ingress, encountering mixed face conditions, low ground cover, presence of sensitive buildings and structures within the influence zone of the excavation, presence of boulders, abandoned foundations or uncharted utilities and sophisticated geometrical configurations. NATM minimizes impacts on traffic and utilities/services throughout construction, reducing disruption to lifestyle.

A. Basic Principles Of Natm

1) To preserve the ground strength by preventing the ground from loosening.
2) Shotcrete protection to preserve the load-carrying capacity of the rock mass.
3) Monitoring the deformation of the excavated rock mass.
4) Providing flexibility but active supports.
5) Closing of invert to form a load-bearing support ring to control deformation of the rock mass.

B. Rock Support System Based On Rock Classification

Rock Class	I	II	III	IV	V	VI	VII	VIII
Sealing Shotcrete	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Forepole	X	X	X	Yes	Yes	Yes	Yes	Yes
Wire Mesh	X	X	Yes	2 layer	2 layer	2 layer	2 layer	2 layer
Shotcrete (mm)	50	100	150	250	300	300	300	300
Lattice Girder	X	X	X	Yes	Yes	Yes	Yes	Yes
Rock Bolt	X	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Figure Rock Classification.

C. Sequence Of Excavation

3 Top Heading & 1 Benching

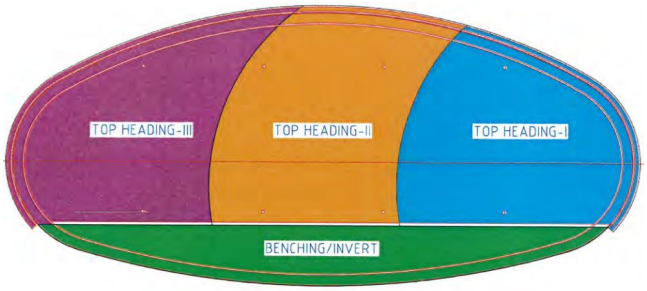

Figure NATM Sequence

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1) Excavation will start in the top heading section I. excavation completes 30-40m top heading section II will Start & Likewise Section III.
2) 30-40m Gap is maintained between all three sections & then
3) Benching excavation will start.

D. NATM Support Elements

1) Fore Poling

a) Fore poling and lagging are support measures installed in the tunnel longitudinal direction prior to excavation.
b) They shorten the FREE SPAN of the unsupported excavation surface. Fore poling and lagging are only support aids for the excavation and will have less function after installation of initial supports(rib, shotcrete, wire mesh, rock bolt etc.).

2) Drilling

a) Drilling will be done using hydraulic drilling jumbos.
b) Hydraulic Drilling Jumbos- 2, 3 Jumbos, 1 Basket Jumbo.
c) The drilling boom is set out and positioned.
d) The blast holes will then be drilled as per the drilling pattern.
e) After drilling, Blast holes will be checked and cleaned to depth blown out with compressed air to remove sludge and water.

Figure Hydraulic Jumbo Machine

f) Blast Hole Diameter = 45mm
g) Blast Hole Depth = 3m
h) Blast Hole Spacing (Burden) = 900mm-1000mm is maintained.

3) Loading

a) Explosive Charging should be done always from the top to bottom (above booms, about safety reasons).
b) Charging up to 2m heights should be done always in safety distance to drilling boom.

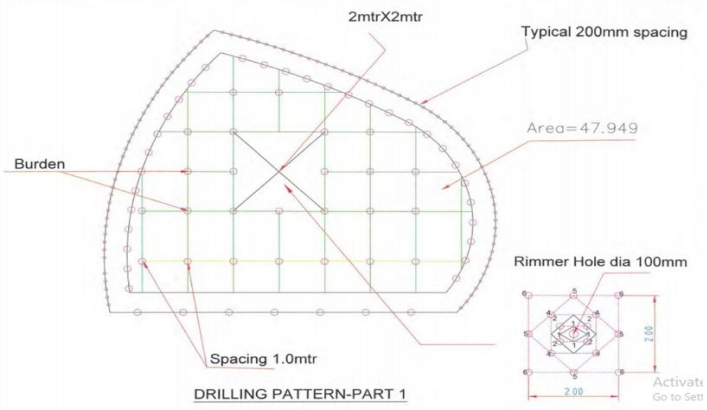

Figure Drilling Pattern

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4) Blasting

a) Once all holes have been charged excess explosives shall be removed from the blasting area.
b) The detonating cord shall be laid out along the face and the detonators hooked to the cord.
c) The face to be blasted shall then be thoroughly checked to ensure that all detonators are hooked up to the detonating cord.
d) While charging of blast holes is ongoing the blasting wire for electric initiation will be laid out simultaneously.
e) The blaster shall fire the round from the designated firing site – at least 30m-40m from nearest hole.

• Name:	Ideal Prime Explosive.
• Type:	Emulsion Explosive.
• Density:	1.15-1.25 gm/cc
• Shelf Life:	6 Months.

Table Explosive Specification

5) De-fuming

a) Blast area shall be de-fumed by ventilation fans to allowed dissipation of smoke, fumes, and dust generated by the blast.
b) To provide fresh air supply to the faces when work cycle is going on at the face.
c) The tunnel safety officer or the tunnel Supervisor shall enter the tunnel area and declare the area safe to work.
d) Tunnel Lights are reinstalled.
e) Water will be sprayed at face to clean it for face mapping.

6) Mucking

a) Mucking is done by using Bucket Loader & Dumpers.
b) Bucket Size = 1.5 cum
c) Capacity of Dumper = 14 cum

7) Scaling & Trimming

a) After the blasting the Scaling of the face above the tunnel muck will be done.
b) Scaling and trimming of the blasted profile will be done to remove loose rocks resulting from the blast and to trim any under breaks.
c) To ensure the excavated profiles con-form to the design profiles as indicated in the design drawings.
d) Parallel dozing of the muck will be done by the loader.

Figure Scaling & Trimming

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8) Face Mapping

a) After Trimming and Scaling the excavated profile will be checked by survey and geological mapping done.
b) To obtain the required geological and geotechnical information before applica-tion of sprayed concrete on the blasted area.
c) Under breaks will be marked, and will be removed and re-excavated to the design excavation limit.

Figure Face Mapping

d) If the profiles confirm to the excavation design limits, the blasted surface will be thoroughly cleaned.
e) Surface is purged by water spray to remove loose rock fragments dust, and sludge adhe1ing to the rock surface.
f) The application of a sealing layer at round and at the face will be done immediately after the mucking and scaling operations.
g) If required and / or the installation of local rock bolts to secure individual blocks against rock fall.

9) Shotcrete

a) Shotcrete is the generic name for cement, sand and fine aggregate concrete.
b) It is applied pneumatically and compacted dynamically under high velocity.
c) In NATM technique, shotcrete as the first choice for primary support in tunnels has been extensively applied.
d) It is versatile in shape, high Strength, Durable, good bonding ability, and in areas of difficult access it can be easily sprayed onto a surface.

E. Function Of Shotcrete

1) Sealing shotcrete is used to avoid lose ground and prevent fall-downs.
2) Protecting layer or umbrella under which workers and machines can perform safely.

F. Sealing Layer

1) Shotcrete Thickness of Sealing Layer = 75mm.
2) Grade = M35 – Wet Shotcrete.
3) Accelerator – BASF Master OC SA160 (5% - 7% by weight of cement)

G. 1ST Layer Shotcrete

1) After support installation i.e. Wire mesh - shotcrete is done for 1st Layer.
2) Shotcrete Thickness of Sealing Layer = 75mm
3) Grade = M35 – Wet Shotcrete
4) Accelerator – BASF Master OC SA160 (5% - 7% by weight of cement)

Figure Shotcrete

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H. Final Layer Shotcrete

1) Main shotcrete is used to carry load introduced by ground in the lining.
2) The bearing plate and end nut shall be fixed after second layer of shotcrete.
3) If the shotcrete Surface is uneven, padding shall be done with cement & sand mortar.
4) Then bearing plate can be fixed properly (perpendicular to face).

a) Wire Mesh

- Stabilization of applied shotcrete until setting and hardening.
- Increase of shear strength.
- Reinforcement of construction joints.
- Reduction and limitation of shotcrete cracking due to creep and overstressing.
- Preventing dropping of shotcrete portion after cracking or failing of the lining.
- SIZE: Standard size is 150 x 150 x 6 mm.
- Wire Mesh installation is done with Jumbo Basket.

Figure. Installation of Wire mesh

b) Systematic Rock Bolting

- Locations of rock bolts shall be marked by surveyor as per the drawing.
- Drilling of rock bolts shall be performed using Drill Jumbo Machine.

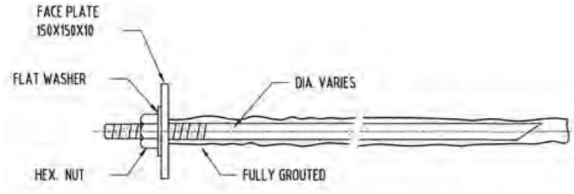

Figure. Rock Bolt

- Drilling Diameter = 38 mm.
- Drilling Depth = 4 M.
- Rock bolt Diameter = 25 mm - SN Bolts.
- Anchor Plates Size = 200 x 200mm x 12mm.

Figure. Rock bolting

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- After Drilling holes are cleaned.
- Installation of Rock bolt is done manually with the help of drifter.
- Space between Rock and Rock bolts in the drilled hole is filled by Cement Grout with the help of Mai Pump.
- Cement Grout =50 kg.
- W/C Ratio = 0.37 (18.15kg)
- Admixture – Ant-shrinkage Cebex 100 fosroc= 225gm.

Figure NATM Profile

IV. CONCLUSION

Tunneling in urban areas is becoming highly viable as a result of advancement in technologies, application of safety measures, implementation of risk mitigation strategies, and efficiency in design and construction. Properly implemented, it will avoid cut-and-cover construction and its associated impacts on traffic, utilities, businesses and the public.

The method of NATM consisting of preparatory work, surveying, drilling, charging, blasting, ventilating, mucking, scaling, shotcreting, and rock bolting.

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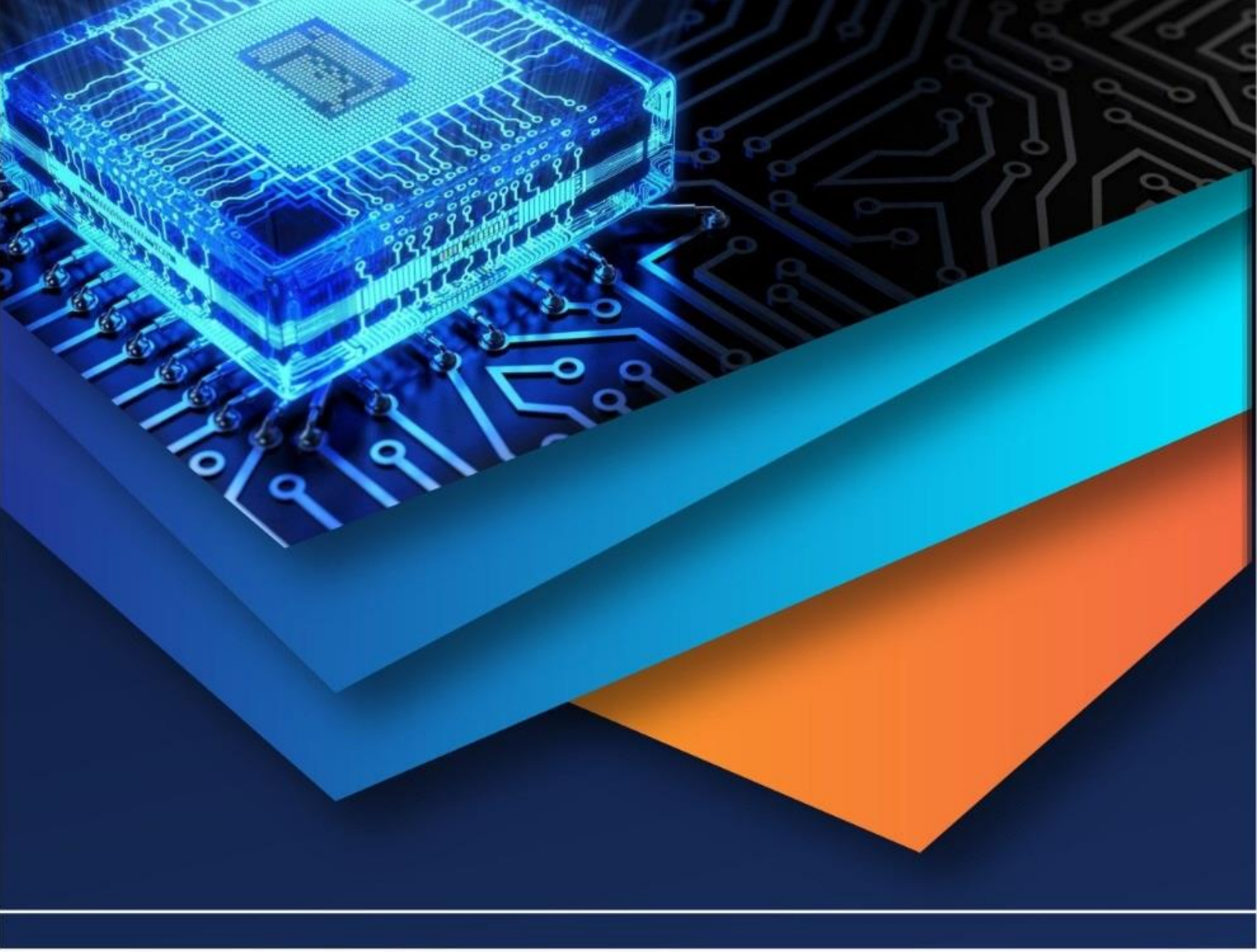

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