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Review on Tunnel Construction by New Austrian Tunneling Method

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Abstract - *This paper describes the advanced concept used for underground construction i.e., New Austrian Tunneling Method (NATM) in Indian Metro Rail. Metro Rail system in India is elevated as well as underground also. First metro of India i.e., Kolkata Metro is constructed using Cut & Cover Method and Shield Tunneling. But from Delhi Metro most of the Metro Rail in India are constructed by using Tunnel Boring Machine (TBM) and New Austrian Tunneling Method (NATM). NATM is commonly adopted at both sides of underground stations for providing safe opening for TBM launching and outbreak. It is not a method but a concept of construction of underground structures. It has often been referred to as "design as you go" or "design as you monitor" approach to tunneling. It integrates the principles of the behaviour of rock masses under load and monitoring the performance of underground construction during construction. This tunneling concept is adopted in Pune Metro Rail Project at both sides of underground stations for providing safe opening for TBM launching and outbreak. This concept is about flexibility in drilling and construction depending on the results of the ongoing monitoring work. The operation occurs sequentially to take most advantage of the ground conditions. Additionally, NATM installs ground support on the go and on an as-needed basis, adding reinforcement to the shotcrete where necessary. The final and permanent support is usually (but not always) a cast-in-place concrete lining placed over a waterproofing membrane. Constructional aspects of NATM in India will be discussed at length in this paper. Its philosophy and construction method yield a more cost-effective, flexible tunnelling operation when compared with the other methods.*

Key Words: Indian Metro Rail, NATM (New Austrian Tunneling Method), TBM (Tunnel Boring Machine), Shield Tunneling, etc.

1. INTRODUCTION

NATM was introduced by Rabcewicz in 1964. NATM is not a method but is a concept with uniformity and sequence. It can be defined as a support method to stabilize the tunnel perimeter with the help of sprayed concrete. It was originally developed for weak ground, i.e. where the materials surrounding the tunnel require rock supporting works because they are overstressed. The method is by many regarded as synonymous with shotcrete because this method of rock support plays an important role (A. Palmström, 1993). The new Austrian tunneling method (NATM) has been recently introduced as an economical alternative to conventional shield techniques for the construction of tunnels in cohesive soil. It was used in soils for the first time in West Germany on the Frankfurt metro (E. Leca & G. Clough, 1992). The NATM requires the distortion of the ground to be kept to a minimum (in order to avoid softening and thus loss of strength). But at the same time sufficient ground deformations should be allowed in order to mobilise the strength of the ground (K. Kovari & P. Lunadi, 2000).

1.1 NATM Concept

NATM was introduced by Rabcewicz in 1964. The name NATM is misnomer as it is not a method but is a concept with uniformity and sequence. It can be defined as a support method to stabilize the tunnel perimeter with the help of sprayed concrete, anchors and other support and uses regular monitoring to control stability of the tunnel. It is not a set of specific excavation and support techniques; it has often been referred to as a "design as you go" approach to tunnelling, by providing an optimized support based on observed ground conditions.

1.2 Principles of NATM

1. Prevention from disintegrating of rick mass, hence keeping it strength.
2. Rock mass qualification.
3. Shotcrete protection (Preliminary support).
4. Monitoring the behaviour.
5. Construction measures.

3. CONSTRUCTION SEQUENCE OF NATM

1) Profile Making
2) Face Drilling
3) Charging ang Blasting
4) De-fuming
5) Mucking
6) Scaling (if required)
7) Geological Face Mapping
8) Face Sealing Shotcrete
9) Lattice Girder Erection
10) Fore Polling (if required)
11) 3D monitoring Targets Installation
12) Initial Lining with Shotcrete
13) Rock Bolting and Grouting

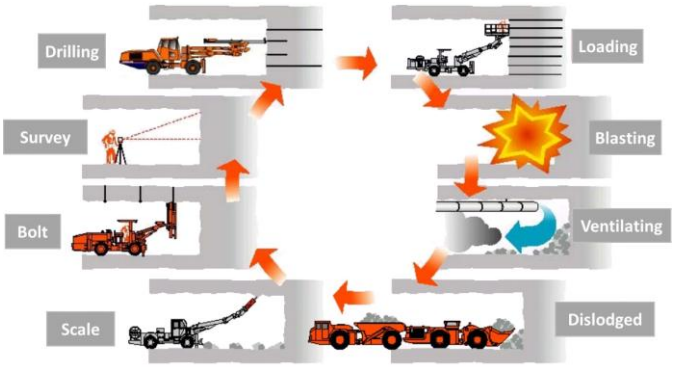

Fig -1: NATM Sequence (RSU International Research Conference, 2019)

2.1 Profile Making

To achieve the designed shape profile marking is required. Its main purpose is to define the minimum excavation line on the working face. Accuracy in profile marking helps to maintain the minimum excavation line and avoids over breaks.

2.2 Face Drilling

Once the profile is marked working face is drilled with the help of 2 boom hydraulic boom Jumbo (figure 2). There is various drilling pattern. Number of holes (variable) are drilled. The Number as well as length of holes (pull length) varies, depending on the rock type, if the rock encountered is in good condition then length of the hole can be increased. Generally, 1m, 1.5m, 2m pull lengths are used here, depending upon the Rock class.

Fig -2: Drilling by drill jumbo

Fig -3: Charging.

2.3 Charging and Blasting

The drill and blast method is characterized by operations that occur in a repeated cyclic sequence. The level of automation and mechanization of these tasks is low and there is a high degree of hard manual labor involved. Incorrect blasting pattern design can cause many technical, economical and safety problems. Inserting the Explosives and charging them for blast is termed as charging and blasting. Charging of holes is done manually by expert staff. By using Drill Jumbo's basket manpower is lift and hole charging is done. Non-electric detonators are used with for charging. Figures 3 shows the charging operation.

2.3.1 Blasting Pattern

In the tunnel face, holes are drilled with different pattern with the drill holes potentially having a different lengths and angles. Different hole patterns are available resulting in different collapse mechanism. It is very difficult to select the most suitable pattern among several possible patterns. It depends on rock quality. There are various patterns like Angle cuts, Wedge cut, Parallel Holes, Conical Cut, Fan cut, etc.

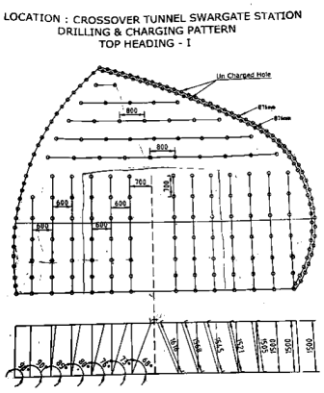

Fig -4: Blast Pattern

Fig -5: De-fuming

2.4 De-fuming

Once the blast is taken various harmful gases are emitted in the tunnel. Expelling out these harmful gases is termed as de-fuming as shown in figure 5. The blast area IS de-fumed by ventilation fans to allow dissipation of smoke, fumes, and dust generated by the blast A minimum of 15-30 minutes is required for de-fuming.

2.5 Scaling

Once mucking is completed the whole blasted area is thoroughly checked for presence of undercuts or some loose material or cracks which are removed with the use of excavators or breakers as shown in figure 6. Scaling is necessary to provide accurate excavated profile for the installation of Lattice girders and safety of the workers executing the works.

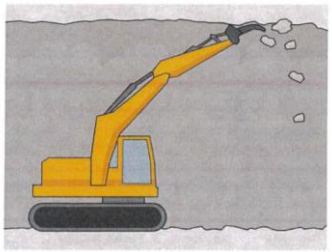

Fig -6: Scaling

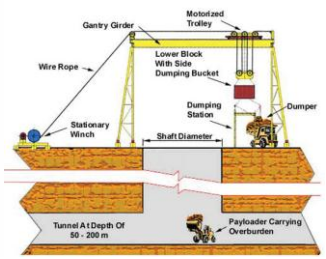

Fig -7: Mucking

2.6 Mucking

The operation of loading the rock, earth or any other excavated material for removal from the tunnel is referred to as mucking. The methods are as follows, shown in figure 7. Machinery used for mucking depends on the availability of working area inside the tunnels. It is done either by hand or by using machinery and it's depended on availability of space. Machines used for mucking are loaders, dumpers, excavators, etc.

2.7 Geological Face Mapping

Examining the types and number of joints and type of rock conditions of the obtained face is termed as geological mapping. After scaling and chipping geologist along with survey team and other supporting workers inspect the face. Geologist examines the face and prepares a face log after every pull and keeps a record of the same. Depend on information collected geologist decided whether designed support is enough or less or more for that section. Whereas Survey team examines if any over break is there or not.

2.8 Face Sealing Shotcrete

To avoid falling of loose materials, a protecting layer is applied on the obtained face and the periphery which is called as face sealing shotcrete. Minimum 30-50mm face sealing is applied depending on the site conditions. The main purpose of applying face sealing shotcrete is to prevent any casualty which may happen due to falling of loose material from the excavated face.

2.9 Lattice Girder Erection

Lattice girders act as initial support and provides a defined shape to the tunnel. It may be used or may not be used depend on soil or rock quality and stand-up time.

2.9 Fore Polling

Fig -8: Fore Polling

The process of installing fore poles is termed as fore poling. In case of weak rock in the crown portion fore poles are provided for additional support. It is done only if it required. The material used is Self-Drilling Anchor which is installed with the help of 2 boom hydraulic jumbo. Moreover, they are passed through the lattice girder to counter the weight of the rock mass in the with and without fore poling. Its use is also depending on soil or rock quality and stand-up time.

2.10 3D monitoring Targets Installation

The NATM principle includes the 3D monitoring instrumentation, which plays a very important role in tunneling. It is used to find out whether the support system is sufficient for the particular rock type or not. In instrumentation the 3D monitoring targets are installed to check the deformations inside the tunnels after the excavation.

2.11 Initial Lining with Shotcrete

Shotcreting or sprayed concrete is considered as one of the main components of initial support system. It is ideally suited for the support and construction of underground excavation in earth and rock structures. Shotcrete is applied and compacted with compressed air using the wet or dry process, hydrates on the substrate and hardens. Shotcrete provides support immediately after an advance with optimal bonding to the rock mass. The process provides specific quality enhancement that interact with the ground surface and prepared substrates, providing superior bond characteristics, increased density, resultant strength, durability, and toughness. it can provide early construction support in rock with limited "stand-up" time.

Fig -9: Shotcrete

Fig -10: Rock Bolting

2.12 Rock Bolting and Grouting

After the application of shotcrete rock bolts are installed to stitch the whole shotcrete with the rock so compact that shotcrete and rock becomes one unit for supporting the whole burden. If rock bolts are anchored by grouting, then it is necessary to investigate on a case-by-case basis to what extent is applicable. Rock bolts are normally used to secure the correctly profiled excavation outline until the final lining is installed, but also to support the face. Until the final lining

is complete, rock bolts have to prevent rupture and falling rock in order to avoid the surrounding ground weakening and thus further deformation.

3. CONCLUSIONS

NATM is based on the observational approach whole outcome depends on the Geological interpretation and 3D Monitoring data. This method provides flexibility to change the support systems at regular intervals depending on received data from face logs and 3D monitoring. NATM is not perfect, needing much coordination, cooperation, and communication to compete with the other construction methods. And even at peak performance, NATM typically performs at a slower rate than the other methods as the team adapts to changing conditions. The operation occurs sequentially to take most advantage of the ground conditions. Additionally, NATM installs ground support on the go and on an as-needed basis, adding reinforcement to the shotcrete where necessary.

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