NEW AUSTRIAN TUNNELING METHOD

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Introduction

NATM is not a construction method for tunneling it's a *strategy for the smooth work of all the construction activities* with safety and economy being the main principles. *Flexibility* in the operation and construction works is the main advantage of the NATM technique. It can be used for hard rock conditions, soft rock conditions, and for mixed ground conditions as well.

Before starting the construction activity, it is of utmost importance to know the geology and geotechnical features of the ground. To have a good idea about the ground conditions boreholes at the required locations are taken.

GENERAL SEQUENCE FOR THE CONSTRUCTION USING NATM

Marking of Drill Holes

In this process, drills are marked on the face of the tunnel based on the blasting pattern. Whether, a wedge cut or a burn cut.

Drilling of Holes

In this process, holes are drilled using manual excavators if the face is of soft soil/rock or with the boomer machines if the face is of hard rock.

Charging with Explosives

In this process, explosives are inserted into the drilled holes and are connected with detonators. Finally, all the detonators are connected at one prime connection.

Charging and Blasting

In this process, the prime connection where all the detonators are connected is exploded which consecutively allows the explosion of each explosive placed in each drilled hole at a designed interval (generally at a 1-millisecond interval).

Scaling and Mucking

This process starts after the complete removal of the dust and harmful gases which occurred during blasting. In this process, loose cuts which remain intact on the face are removed.

Installation of Primary Support

This is one of the most important and tricky parts as the standup time on the ground plays a vital role. Standup time is nothing but the duration for which the unsupported ground remains stable on its own after blasting or manual excavation. In primary support measures, shotcrete or rock bolts are used. The thickness and grade of shotcrete and length, type, and diameter of rock bolt depend upon its design.

The construction of the tunnel can be subdivided into parts, such as heading, benching, and inverting.

Provision to Avoid Ingress of Water

Water ingress inside the tunnel is the major concern as it may lead to the failure of the structure. To avoid this situation waterproofing membrane in the form of a Dimplex or Nyllex strip is provided, after the installation of the primary support system.

Secondary Support or Extra Structural Support

If the strata demand more support and structural stability, supports in the form of a Lattice girder, steel ribs, second layer of shotcrete, etc. can be provided.

Final Lining

In this process, a kicker beam of precast or cast in situ sections is installed, followed by kicker lining throughout the periphery of the tunnel section.

SUITABILITY OF NATM

For the construction of any tunnel, choosing of appropriate construction technique is the most important aspect. Analysis of whether to go for NATM or TBM is vital.

Following are some situations where NATM is suitable

• For projects with highly varying ground conditions, the methodology can be altered according to the changes in geology.

• As this is a flexible technology it can be used for different geometry of the tunnels. By changing the blasting patterns required geometry of the tunneling sections can be achieved.

• When there is a high risk of water inflow precautionary measures can be taken like pipe roofing, fore polling, etc. Installation of waterproofing membranes can also be used wherever required.

• Sometimes TBM installation is difficult due to the congestion and inadequate space at the site. In such cases NATM is preferred as the construction area required is less compared to TBM.

• NATM is mainly beneficial for small-length tunnels as the number of explosives and detonators is less compared to that in longer tunnels. Environmental, Ecological Issues may occur due to the abundant use of explosives.

GROUND STABILIZATION TECHNIQUES

Sometimes it is necessary to improve the ground conditions before the actual construction of the tunnel. In some cases, problems such as high ingress of water or cavity formation, etc. may occur during construction activities and these are one of the riskiest and most hazardous effects. To avoid these situations ground stabilization is done by following methods.

Ground Improvement

Geological faults or fissures can be stabilized by this method. Failure due to cavity formations can also be rectified. In this method, jet grouting is done from the ground surface or from the tunnel, whichever is nearer to the fault, fissures, and cavity. Jet grout is nothing but slurry-based concrete that is applied under pressure to fill the faults, fissures, and cavities.

Ground Reinforcement

In this method, a structural element such as bolts, anchors or piles, etc is inserted.

Dewatering

In case of ingress of water due to water table or underground water flows structural stability of the tunnel can get hampered. To avoid these dewatering or lowering the water table is done.

NATM FOR SPECIAL CROSS-SECTIONS

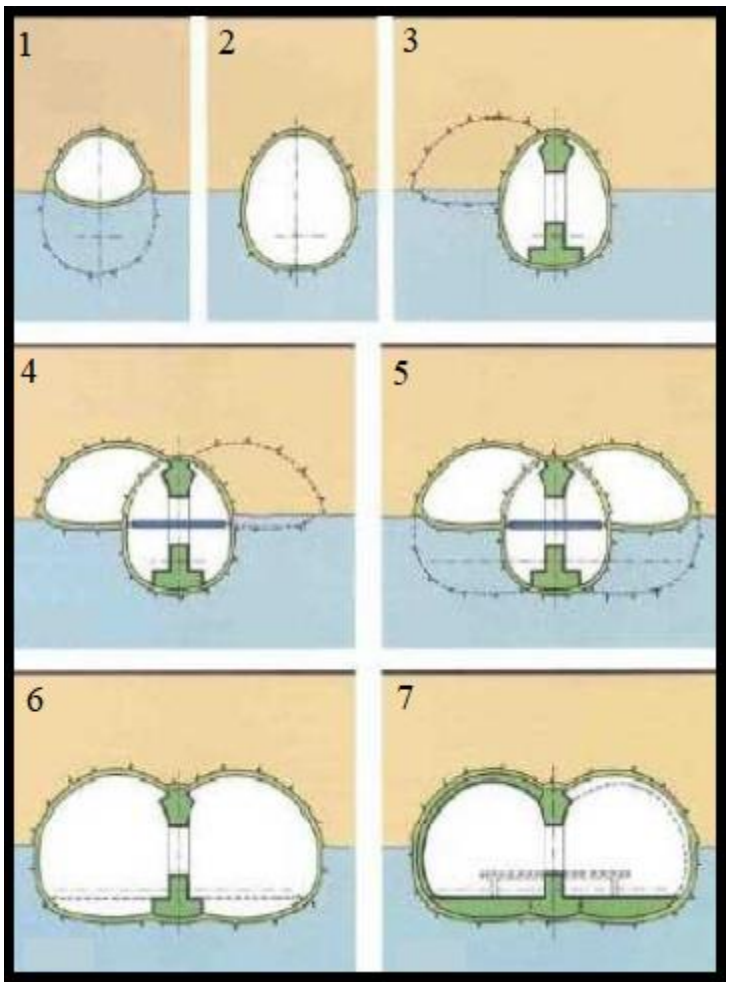

Figure 6

This is the classic example, which suggests how NATM is very beneficial for various types of shapes as methodology is flexible and can be changed according to demand. In this figure construction of two parallel tunnel tubes is shown. In 1st phase of construction, only the heading part is constructed followed by its benching and invert in 2nd phase. Thereafter Column is constructed in between the excavated portion to take and distribute the load from the two adjacent heading portions as shown in the 4th and 5th phases. After that benching and inverting are constructed in the 6th phase. In 1st and 2nd phases, the structural members of the side walls temporarily distribute the load of heading through the column. After completion of the heading and benching part of the adjacent tubes as shown in phases 5th and 6th, the temporary structural side wall supports are removed. NATM becomes very useful in such complicated construction methodologies where flexibility in construction sequence is essential according to the demands.

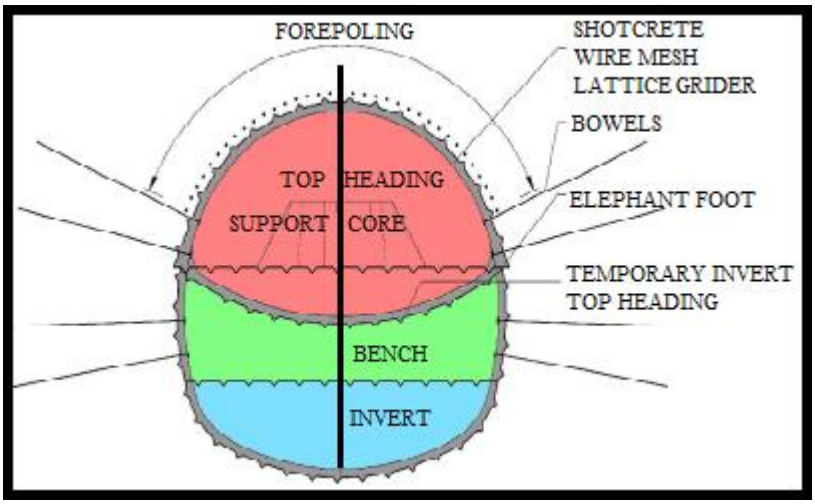

Figure 7

This is a typical cross-section of the tunnel which can be achieved by NATM. In this section heading part is excavated first and after certain progress in the heading excavation once the heading portion ahead gets stable excavation of benching and invert is started. After the excavation of the heading portion elephant foots are provided at the bottom to support and distribute the load from the heading. During the excavation of the heading, a temporary invert is also excavated to avoid stress concentration at the corners. By providing a temporary invert shape the heading section is adjusted to have considerably minimum stress concentration at corners. As NATM is a flexible technique we can optimize the cross-section of the tunnel as per the requirement economically. The main considerable point here is if invert portion is strong in the first place with enough strength we don't require to excavate the invert portion and then again fill it. Whereas in TBM as the shape of TBM is circular we excavate the full section even when invert portion is not required to be excavated. Considering this point NATM proves to be very economical due to these tweaks in the methodology, so NATM is a very optimum and economical method.

Design and Monitoring Concepts

This Is a very important concept as it mitigates the hazard and risks during the construction phase. An alarm plan is designed, in which 3 different levels of the alarm are set corresponding to anticipated or allowable settlement criteria.

Level 1 – Warning level (70% of allowable settlement) Level 2 – Standby level (90% of the allowable settlement) Level 3 – Alert level (100% of the allowable settlement)

GENERAL GEOLOGY BEHAVIOR

Knowledge of geology is very important for NATM, as well as TBM as a structural support system, depending on geology only. Some of the geological behaviors and measures to be taken are as follows

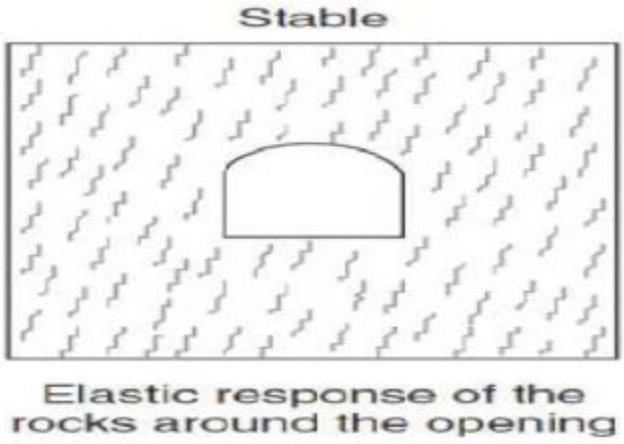

Figure 8

The elastic response around the tunnel section is considered stable.

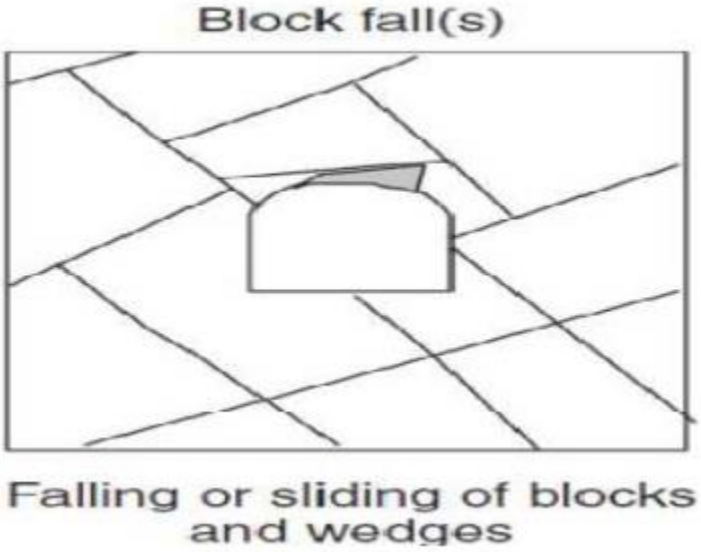

Figure 9

In this case, rock bolts can be used to stitch the faults and stabilize the rock fall.

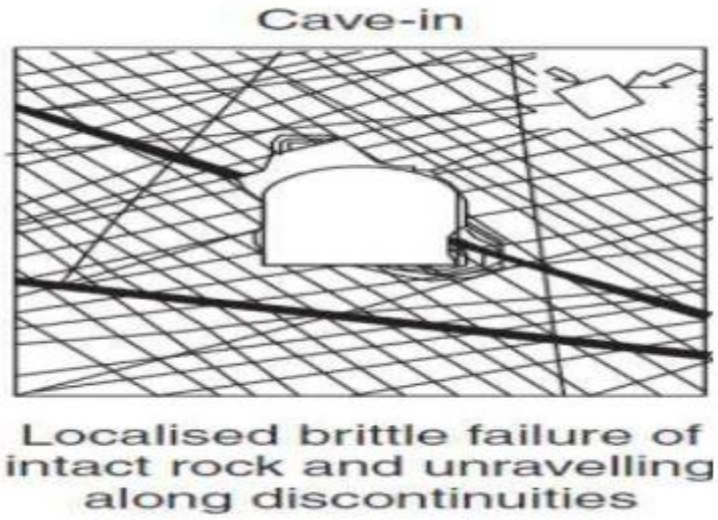

Figure 10

To avoid failure due to cave in rock filling or grouting is done to fill the cavity completely.

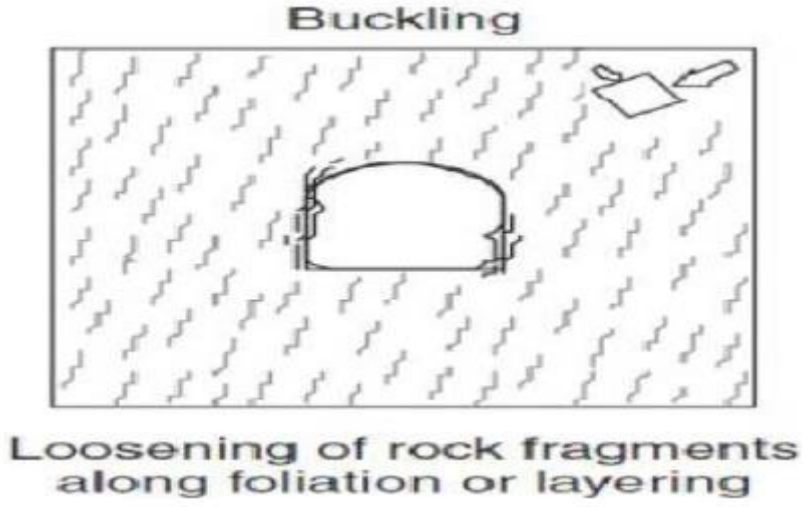

Figure 11

To avoid the buckling of the tunnel side walls should be strengthened with the use of lattice girders, steel arches ribs, shotcrete or anchors, etc.

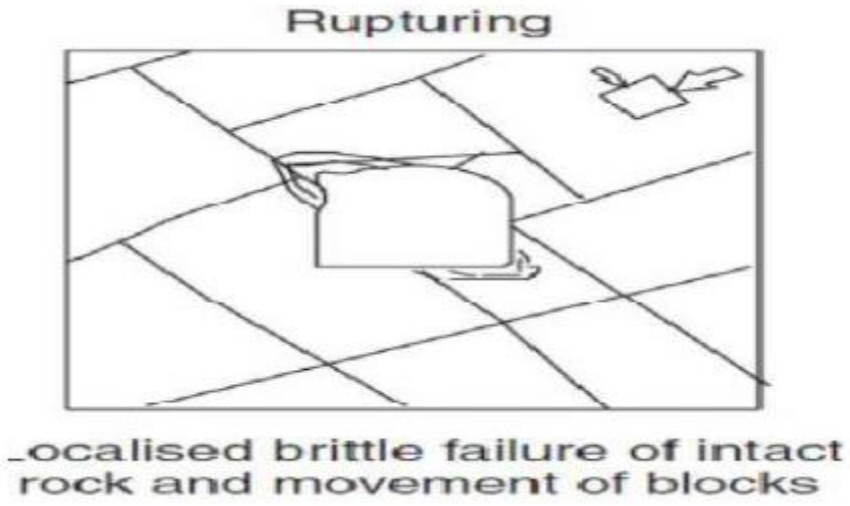

Figure 12

Permanent anchors are provided to avoid rupturing.

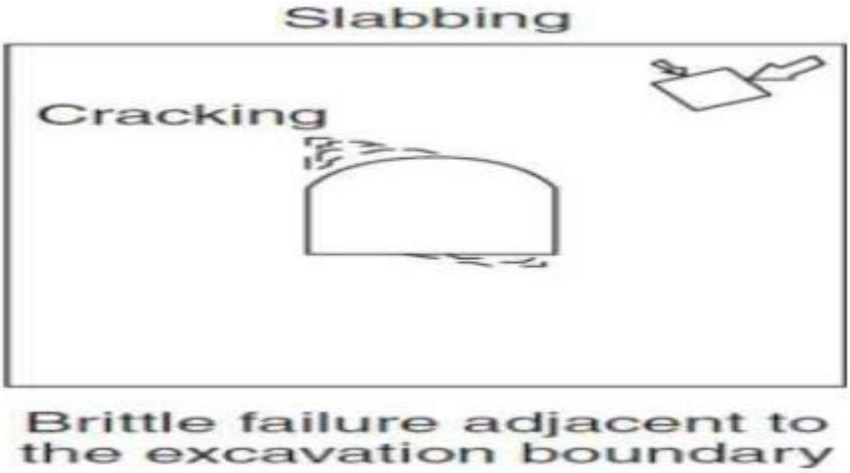

Figure 13

Fore polling and grouting should be done to stabilize and avoid further cracks due to slabbing.

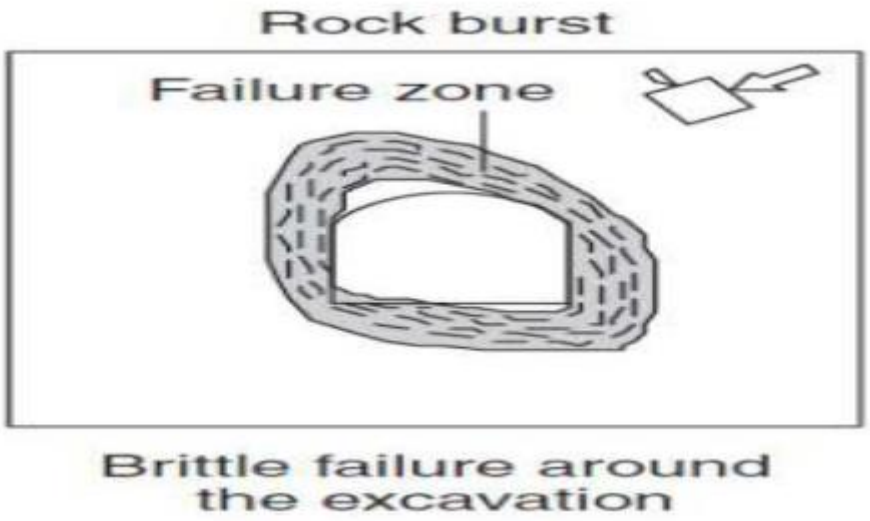

Figure 14

Rock burst is a relatively unpredictable situation. To avoid the rock burst in burst-prone geological conditions excavation technology should be modified with changes in blasting and drilling patterns.

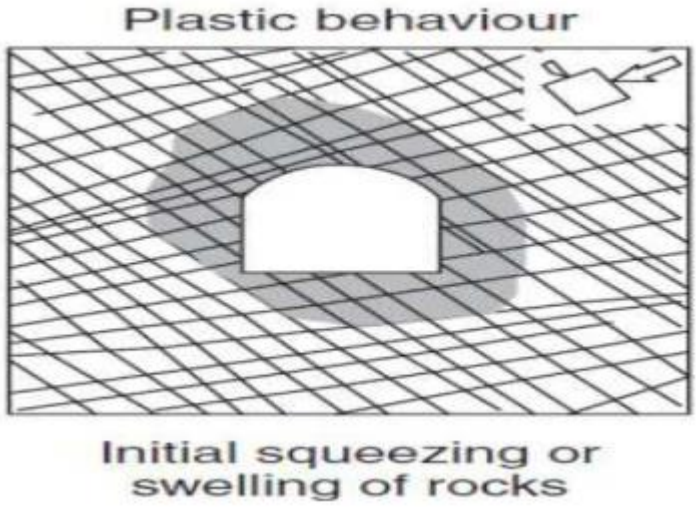

Figure 15

If plastic behavior with squeezing or swelling of rocks is observed geometry of the tunnel section should be modified. Circular geometry which distributes the stress around the tunnel Periphery smoothly can be the solution. The stiff lining is also required