PIR PANJAL RAILWAY TUNNEL

By N.A.T.M. METHOD

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Presentation covers;

- **Overview of JURL project, especially Pir Panjal tunnel.** Pir Panjal tunnel (T-80) is the part of JURL project. This is the longest rail tunnel of India (10.96km). When completed, this will provide alternate high capacity, reliable means of transport to Kashmir valley, not vulnerable to frequent closures due to snow fall and hill slides.

- **Broad Methodology: TBM or NATM?** Why TBM is not being used and what are the advantages of N.A.T.M. (New Austrian Tunneling Method) over TBM for that area.

- **What Equipments & Construction methodologies are being used?** What are the steps involved in NATM along with the instrumentation required at site.

Salient features (Laole-Qazigund)

Udhampur to Katra (30Km): By N R (In advance stage)

Katra –Laole (69Km): By KRCL

Laole –Qazigund (68Km): By IRCON

Qazigund –Baramulla (116 km): By IRCON

No. of stations: Five

Ruling gradient: 1 in 100

Max Curvature: 2.75 degree

Earthwork: 25 lacs cum (approx)

Major bridges: 42

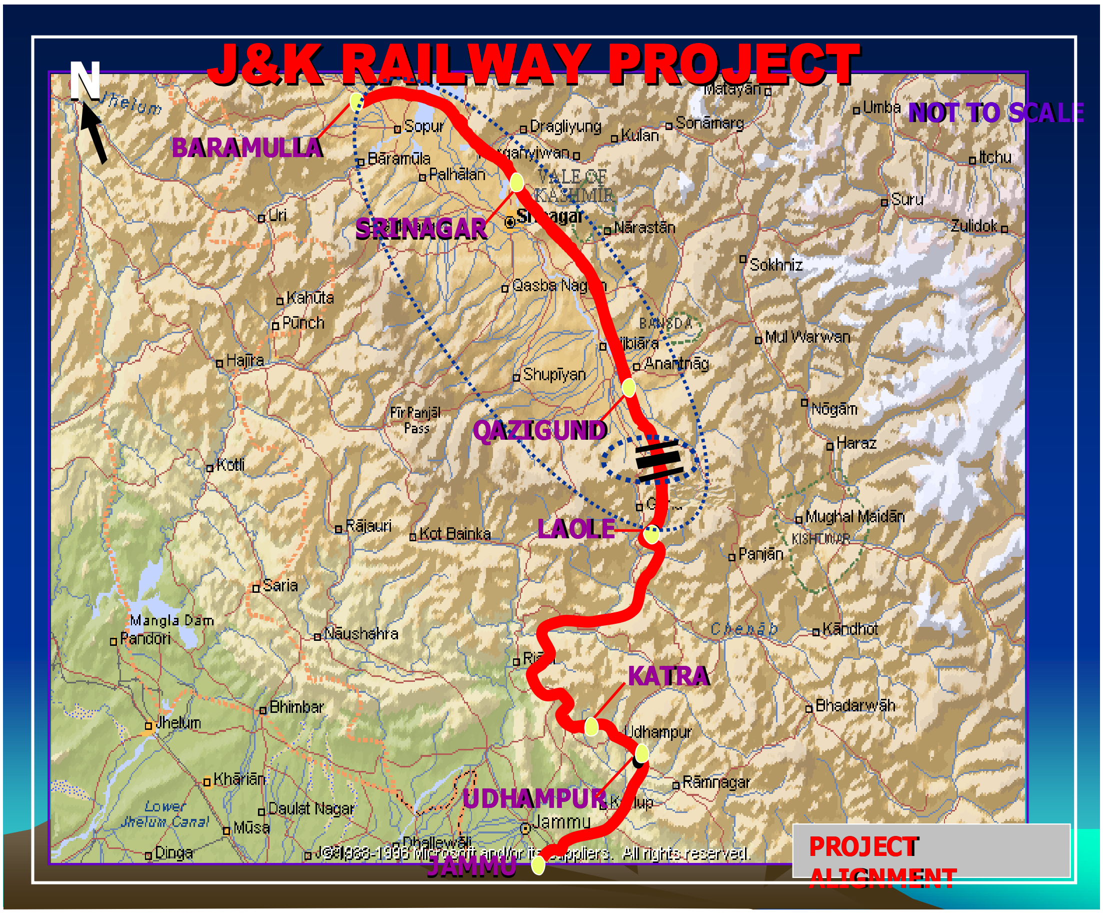
Tunnels: 33 nos(46km)

Longest tunnel: T-80 (Pir Panjal tunnel)

Total cost : Rs 2100 crores (approx)

Uptodate progress : 15% (approx)

Alignment of J&K rail project



Blue encircled portion is being done by IRCON that is from Laole to Baramula. (Out of this Laole to qazigund is with Dy/CE/S&C-4/ Udhampur). Pir Panjal Tunnel (T-80) joins Jammu region to Kashmir valley by crossing Pir Panjal range.

Horizontal Alignment of T-80

The tunnel is completely straight in almost N-S direction
It joins Cheril Village in valley with lower Munda on Qazigund

The maximum overburden is approximately 1150m.

4 km length has an overburden > 500m
650 m length has >1000m.

There is single track tube with side road for repair/emergency rescue.

Clear 3m wide passage is there in the cross-section all along.

Similarly it is outside the portals up to 400m on either side

Vertical Alignment of T-80:

There is a rising grade of 1% from south to the high point at Km 159.134
Subsequently there is a falling gradient of 0.5% up at the end.

This provides for better & easy construction.

It's level is 450 m lower than road tunnel making it less vulnerable to snow

Method of construction (N.A.T.M. VS TBM)

TBM design requires reliable geologic information in the initial stage itself and there is always a likelihood of mixed-face excavation in Pir Panajals.

There is also heterogeneous geology ie soil near portals to Trap and quartzite in middle which is not well suited for TBM.

Heavily faulted areas and/or wide fault zones are also expected, TBM may be trapped by ground movement behind the face.

High squeezing is anticipated in the middle zone with 1150m overburden and likelihood of heavy water inflow in the lime stone zone with heavy over burden.

High initial period needed for ordering, design, manufacture and commissioning of TBM.

Retrieval of TBM's approaching each other requires large cavern

TBM obstructs final lining activity for a long time after break-through

Non circular section can only be achieved by enlargement later.

TBM requires specialized skilled crew and also there is heavy requirement of electric power.
There is a high risk of getting TBM stuck under squeezing ground conditions, in fault zones and in alluvium like situation at the ends.

Designing, tendering, manufacturing and installation of TBM takes 10 to 14 months.

Therefore NATM method was selected for Pir Pnajal tunnel project.

Creation of more faces: adit and shaft

The idea was of shortening the critical length of drive and isolating difficult ground near portals.By providing an adit (south) and a shaft (north), the critical length is now 7600 m only, against the total length of 10.96 km

The shaft at north end and is of 12 m dia & 55 m depth,isolates 600m north end tunnel. Adit tunnel is at south end and is of 690m length.The cross section of the adit and shaft also allow for construction convenience and ventilation during construction and operation besides chiefly creating more tunnelling faces for ease of construction. Adit tunnel follows a down gradient of 10%.

N.A.T.M.

NATM was first proposed by prof. L V Rabsewicz in 1964. In his words "…A new method consisting of a thin sprayed
concrete lining, closed at the earliest possible moment by an invert to a complete ring –called an "auxiliary arch"- the deformation of which is measured as a function of time until equilibrium is

obtained"

He emphasized three key points, the first is the application of a thin-sprayed concrete lining, the second is closure of the ring as soon as possible and the third is systematic deformation measurement

The definition given above has then been redefined by the Austrian National Committee on Underground Construction of the International Tunnelling Association (ITA) in 1980. This is as follows:

"The New Austrian Tunnelling Method (NATM) is based on a concept whereby the ground (rock or soil) surrounding an underground opening becomes a load bearing structural component through activation of a ring like body of supporting ground". Another recent definition on NATM given by Sauer (1988) states that NATM is:

"…A method of producing underground space by using all available means to develop the maximum self-supporting capacity of the rock or soil itself to provide the stability of the underground opening." Using the statement "all available means", he defines the method in a more general fashion than it was already defined by his fellow Austrian practitioners.

One of the other advocates of NATM, Prof. Dr. Leopold Müller (1978) proposed that

i. The surrounding rock mass is the main load bearing component and its carrying capacity must be maintained without disturbance of the rock mass.

ii. The support resistance of the rock mass should be preserved by using additional support elements

iii. The lining must be thin-walled and necessary additional strengthening should be provided by mesh reinforcement, tunnel ribs and anchors rather than thickening the lining.

iv. The ring closure time is of crucial importance and this should be done as soon as possible.

v. Preliminary laboratory tests and deformation measurements in the tunnel should be carried out to optimise the formation of the ground ring.

In summary, the following major principles, which constitute the NATM, can be derived from the following references; Tunnels & Tunnelling (1990), Will (1989), Brown (1990), Wallis (1995), ICE (1996), HSE (1996), Bowers (1997), Fowell & Bowers, (1998) as follows:

i. The inherent strength of the soil or rock around the tunnel domain should be preserved and deliberately mobilised to the maximum extent possible

ii. The mobilisation can be achieved by controlled deformation of the ground. Excessive deformation which will result in loss of strength or high surface settlements must be avoided

iii. Initial and primary support systems consisting of systematic rock bolting or anchoring and thin semi-flexible sprayed concrete lining are used to achieve the particular purposes given in (ii). Permanent support works are usually carried out at a later stage.

iv. The closure of the ring should be adjusted with an appropriate timing that can vary dependent on the soil or rock conditions.
v. Laboratory tests and monitoring of the deformation of supports and ground should be carried out.

vi. Those who are involved in the execution, design and supervising of NATM construction must understand and accept the NATM approach and react co-operatively on resolving any problems

vii. The length of the unsupported span should be left as short as possible

So all this is achieved by the application of an appropriately resistant initial support, to preserve the rock mass strength and it should also accept the necessary deformation and yet resist the loads.

The initial lining is usually Shotcrete, steel lattice girders and rock bolts either singly or in combination-followed by secondary (permanent lining).

Methodology

First of all a thin layer of sealing shotcrete is applied just after excavation.

Lattice girder

Placement of support system (lattice & wiremesh)

Application of primary lining shotcrete

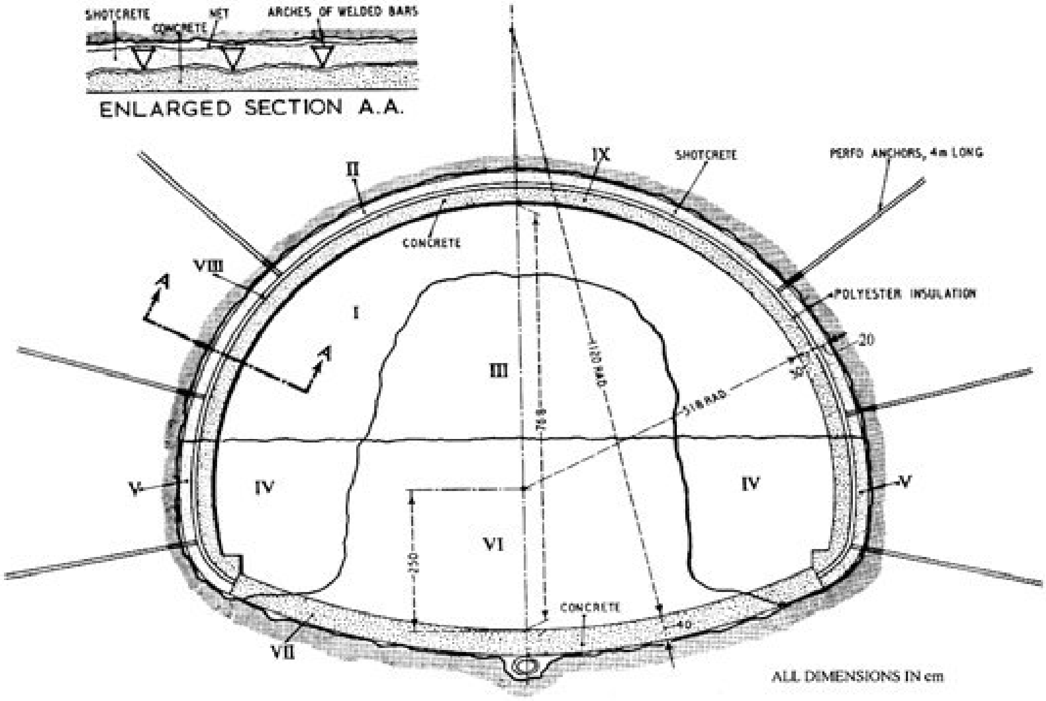
Rock bolting

Excavation in Soft Ground/Poor Rock MassTunneling

The excavation can progress in full face when the rock mass class is excellent,very good,good and then depending upon the inferior rock mass class the excavation can be resoted to heading , benching For further poorer and very poor class of rocks the excavtion can further be divided into the sub-segments.

The excavation face may be divided into small cells that will help the ground stand until completion of the lining It is proposed that the excavation is carried out in six or more steps depending on the size and the geometry of the tunnel. In the figure below roman numbers indicate the excavation order and sequence of excavation for working in soft ground.

The first step is the excavation of the top heading (I), leaving the central part to support tunnel face. Primary lining (shotcrete) II is formed and followed by removing the top central portion (III) subsequently excavation of left and right walls (IV) and then step V & VI so on.



SHOTCRETE
CONCRETE
NET
ARCHES OF WELDED BARS
ENLARGED SECTION A.A.
SHOTCRETE
PERFO ANCHORS, 4m LONG
CONCRETE
POLYESTER INSULATION
I
II
III
IV
V
VI
VII
VIII
IX
A
20
30
518 RAD
1120 RAD
250
40
CONCRETE
ALL DIMENSIONS IN cm

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Advantages

NATM can be adjusted to emerging ground conditions, flexibility in terms of the excavation sequence and support measures.

Excavation can be done with road header, drill and blast

Maximum daily advance peaks of 10 m in stable rock conditions can easily be targeted.

Design part of N.A.T.M.

It mainly consists of design of support system integrated to the deformation characteristics of the ground. Support system can be designed by rock support interaction diagrams.

For getting these, proper Geo-technical modeling (classification of rock mass), rock classifications evolving out of construction sequences and continuous analysis of deformation of primary lining is required.

This continuous real time monitoring allows having an idea of actual stress levels in surrounding mass and also helps in validating design parameters.

Rock support system

The typica rock support system used in the construction of Pir Panjal tunnel T-80 connecting Banihal in Jammu region and Lower Munda(Gulab Bagh) on the valley portion in USBRL project of N.Railway, being executed under Design consultancy of Geoconsult and Rites JV, is as under:

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

Geological Investigations

Pir Panjal mountain range, consists of silicified limestone, andesite ,basalt, quartzite and sandstone , limestone ,shale intercalations and agglomerates shale.

Portal areas are situated in fluvioglacial sediments (soft ground).

The central area of the Pir Panjal range shows a distinct folding. Contacts between rock units are often faulted. Folding is also common especially in central areas.

RITES investigations in 2003 6 bore holes up to 91m depth

RITES investigations in 2004 15 bore hole up to 225 m depth

MECL investigations in 2004 7 bore holes up to 650 m depth.

Instrumentation & Monitoring

In NATM assessment of tunnel stability during excavation is must and is a continuous process to find time until the deformation rate allows inner lining to be installed

This is also to determine additional support measures and adjustments with regards to support and excavation sequences.

For this 3-D optical deformation sections are installed at spacing of 5 to 25m with prism targets around the tunnel perimeter. Other instruments used for the measurement of deformation are Extensometers shotcrete pressure cells, shotcrete strain meters and measurement anchors.

Conclusion:

NATM approach of design and execution of the tunneling in varied geology and especially in soft ground tunneling is advantageous and scientific way of tunneling in comparison to the old /conventional way of tunneling. This system monitors the rock mass deformation and designs the support system with reference to the rock mass type and deformation.