TUNNEL CONSTRUCTION IN PIR PANJAL (HIMALAYA) USING NATM [CASE STUDY T-74R RAILWAY TUNNEL OF KATRA-BANIHAL SECTION OF KASHMIR RAIL PROJECT]

By

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ABSTRACT

The new railway link project between Katra-Banihal is one of the current, most significant Indian projects aiming to join the Kashmir valley with the whole Indian railway network. The T-74R tunnel, going from km 125+310 to km 133+910 (new alignment chainages), is being excavated between the right side of the Bishlari river valley (roughly 5km downstream and southward of Banihal) and the last 5km of the left hillside of its tributary, the valley of the Mahumangat Nallah.The tunnel passes through heterogeneous geology which was highly deformed and having high squeezing property likelihood of heavy water inflow in the limestone zone with heavy overburden. New Austrian Tunnelling Method (NATM) was Preferred over TBM. The New Austrian Tunnelling Method includes a number of techniques for safe tunnelling in rock conditions in which the stand-up time is limited before failure occurs. This paper highlights the various techniques of construction of the tunnel (T-74R) in rugged Himalyan Range.

Keywords: Kashmir Valley, Heterogeneous Geology, Mahumangat, Tunnel, NATM.

INTRODUCTION

Tunnelling is increasingly being seen as an environmentally preferable means of providing infrastructure to densely populated urban areas as well as the areas which are bifurcated by high mountains or water bodies. A national project to link Jammu Region with Kashmir Valley by 293 km B.G Railway Line is undertaken by Ministry of Railways (Govt. of India) in the state of Jammu and Kashmir (Vinod Kumar, 2008). Construction of Jammu-Udhampur-Katra-Quazigund–Srinagar-Baramulla new rail link is the biggest project undertaken by the Indian Railways in the mountainous terrains since independence (Duggal et al., 2001). About 148 km rail line is passing through two steep Himalayan ranges called Shiwaliks and Pir Panjal where more than 75% of the track is through the tunnels. About 84 tunnels, one across Main Boundary Fault (MBF) and many others through thrust and shear zones (NHPC, 1999). The development and design of the rail alignment crossing deep valleys with sheer uneven slopes has been the uphill task for the construction agency (P. Tejal et al., 2014). The T-74R Project IRCON, (2010) tunnel (Figure 1) will mainly cross the rocks belonging to the Ramsu formation and in the northernmost sector of the alignment those referred to the Machail formation. These formations are part of the Tethyan Zone in this sector and the range of the metamorphosed sedimentary cover the High Himalayan Crystalline. The rocks exhibit a NW-SE trend dipping in NE direction. Muree thrust marks the tectonic contact between Tertiary and Pre-Tertiary rocks. It is considered to be an autochthonous folded belt of tightly compressed, recumbent anticline. It lies between the Muree group of foreland and the Salkhala Metasediments of the Kashmir Nappe. Its outer boundary is marked by Muree thrust, which has brought rocks of this par-autochthonous belt over Muree group. The northern boundary is marked by Panjal Thrust, which has brought the entire Himalayan Phenorozoic succession of Kashmir over the lesser Himalayan belt. The curved rail alignment along with harsh seismicity of area poses unique challenges.

1. Description of T-74R

The tunnel T-74R extends between chainage 124.200 km at south portal to chainage 132.840 km at north portal having a shaft and an adit. Tunnel T-74R is ~8.6 Km long and the south and north portal of tunnel located at Chainage 125+310 and 133+910 respectively. The tunnel is being excavated between the right side of Bishlari river Valley (Roughly 5 km downstream and southward of Banihal) and the last 5 km of the hillside of its tributary. i.e. valley of Mahumangat Nallah (Figure 2). The tunnel consists of the main tunnel and an escape tunnel. The length of escape tunnel is shorter than main tunnel. Sump well and pumping system drainage has been used for T-74R. Two air ducts were provided for de-fuming and ventilation purposes. The main method of excavation is drill and blast, however heading and benching is adopted at some places. The construction of T-74R on a new deeper alignment compared to the old one, has been due to the difficulties of excavation encountered during excavation of shallower T-67/T-68 and T-73/T-74 tunnels mainly caused by poor rock mass conditions related to landslide phenomena and faults crossing.

2. Regional Geology

Geologically, the area is occupied by the Ramsu formation which pertains to the middle Proterozoic age and forms a part of "Gunj Syncline". The rock types exposed in the area are phyllitic quartzites associated with phyllites, slates and quartzites. Limestone bands are also present widely at few locations and are yellow to grey in colour. These limestone bands are associated with calcareous phyllites, characterised by soapy touch. Carbonaceous phyllites are black in colour and are seen on the right bank of the Mahumangat Nallah. The rail alignment takes a 'U' turn at the Mahumangat Nallah which is a tributary of the river Bichleri. This Nallah is filled with thick debris and steeply dipping rocks are exposed at few locations close to the Nallah bed. The south portal of Tunnel T-74R is located on the right bank of this Nallah and is close to a major slide zone where weathered limestone is exposed with striking NW-SE at higher elevations (on the hill slope). The dip of the limestone and quartzite band is 40° to 50° towards NE and there may be shear zones associated with it. The Adit-1 site is located near the Kot Nallah and is characterised by an active slide zone. The width of the slide zone is about 70m. Though the slide zone appears to be superficial, its depth extent needs to be ascertained as the thickness of the slide debris appears to be considerable. Geologically, the rocks in the area are predominantly phyllites or quartzitic phyllites. The junction of the escape tunnel with the main tunnel near the north portal of tunnel T-74R lies below the Ladna slide. This slide area has phyllitic rocks with highly weathered micaceous phyllites and slates. The north portal location of tunnel T-74R is covered with soil and rocks of weathered phyllites. Borehole data for BH-6 and BH-7 of the rocks indicates that the rock quality in this area appears to improve with depth.

3. Methodology

The tunnel passes through heterogeneous geology which has highly deformed and high squeezing property, likelihood of heavy water inflow in the limestone zone with heavy overburden. The main advantage of the proposed approach is that, categorization of the deformational behaviour is based on the results of the ground convergence curve and this method has a relatively high degree of reliability. New Austrian Tunnelling Method (NATM) was preferred over TBM. The New Austrian Tunnelling Method includes a number of techniques for safe tunnelling in rock conditions in which the stand-up time is limited before the failure occurs. These techniques include the intact: smaller heading and benching or the use of multiple drifts to form a reinforced ring from which the bulk of the tunnel can be excavated. These techniques are applicable in soft rocks such as shale, phyllites and mudstone in which the squeezing and swelling problems are likely to occur. These techniques are also applicable when tunnelling in excessively broken rocks. NATM was first described as modern tunnelling method by Rabcewicz (1955, 1964, 1973, and 1975). This method makes use of flexible primary lining of shotcrete, wire mesh, lattice girders, rock bolts. In case of weaker rock masses, the use of pipe-fore pole/pipe roofing is also used for crown support which leads to less outbreak and ensures safety during the execution of actual work. The main aspect of NATM is the dynamic design based on the rock mass classification as well as in situ deformations (Rabcewicz 1964). Some important features of NATM include mobilization of the strength of rock mass, shotcrete protection, measurements, lining, closing of invert Rock Mass Classification and dynamic design. The development of NATM has enhanced the cost efficiency of tunnelling projects and had favourable effects on infrastructure development. The New Austrian Tunnelling Method consists in stabilising the ground around the excavation in the most safe and economic manner possible by making extensive use of the bearing capacity of the ground with the help of sprayed concrete and other support elements as well as through the use of measured data (Stipek, 2012).

4. Components and Sequence of Execution of NATM

Face drilling includes drilling of holes for the gelatine explosive horizontally in the face of the tunnel at every section to be blasted. Charging involves loading the particular holes with gelatine explosives. Defuming involves removal of dust from the dig out tunnel due to blasting with the help of ventilators. Mucking involves the removal of large amount of broken rock material. Chipping and filling of overcut follows mucking. A primary layer of shotcrete (50mm) is applied immediately after mucking is complete. Erection of lattice girders and rock bolting follows.

5. Results and Discussions

The tunnel alignment runs through highly fragile rock mass. The bulk composition of Ramsu formation and Machail formation is phyllite with minor quartzite bands in Ramsu formation and Agglomerate slate, tuff, limestone in Machail formation. The phyllites are highly fractured and fragile due to intense folding and faulting. In general, core recovery is good but RQD is poor, indicating that the rock mass is highly fractured and jointed. Deep tunnelling

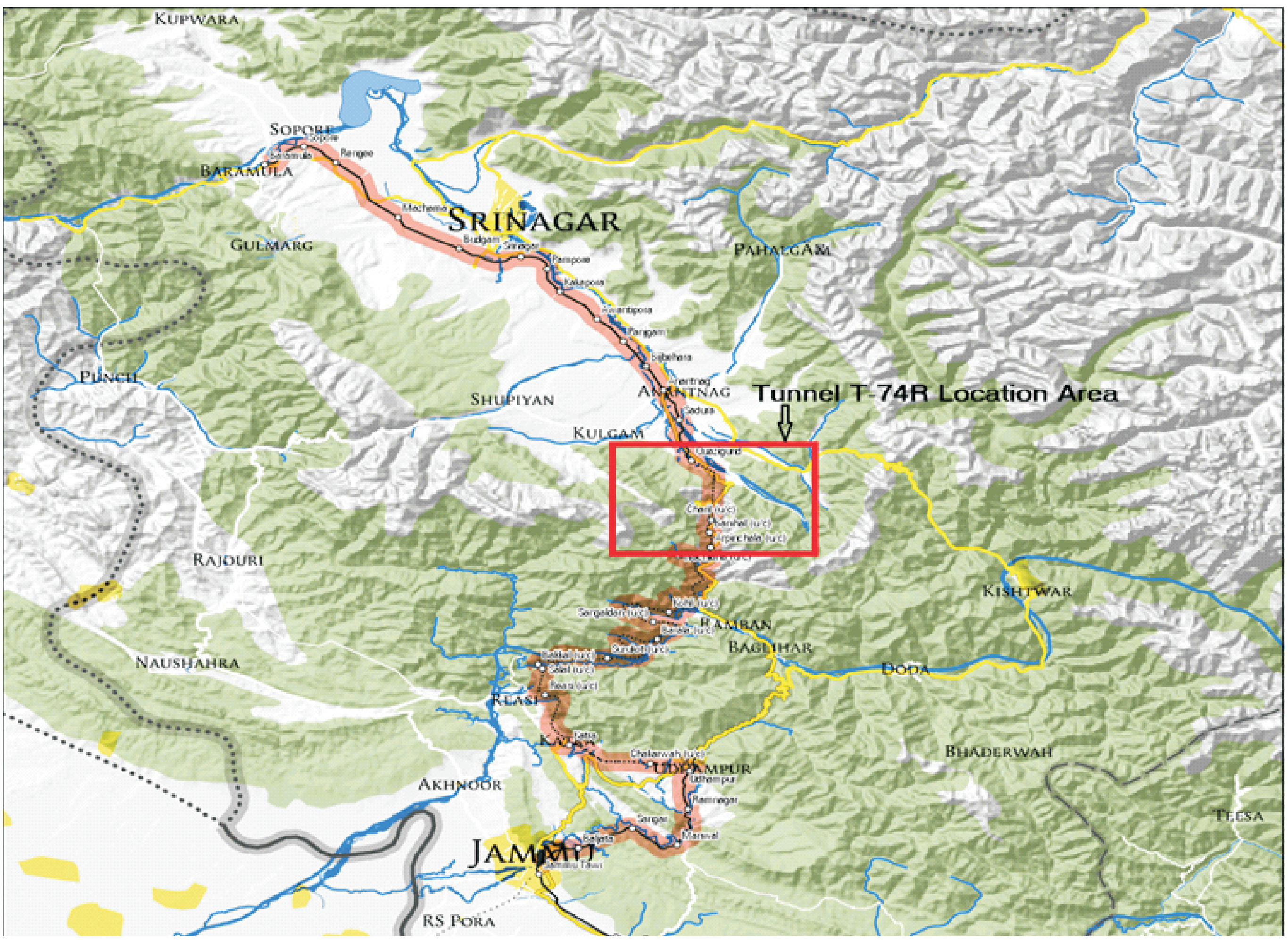

Figure 1. Satellite image of Rail Route in J and K and location area of T-74R (Source: Google Earth)

(>200m) through rock mass is a difficult task where in-situ stresses are high. Some of the tunnelling problems likely to occur will be rock bursting/squeezing and over-break.

5.1 Ground Conditions

The area around the proposed tunnel alignment forms a rugged topography having high hill slopes and deep valleys formed by drainage system mainly controlled by EW flowing Mahumangat Nallah and NS flowing Bichlari Nallah and their tributaries. The proposed tunnel intercepted faulted contact between Ramsu formation and Machail formation at around chainage 132.65 km. Heavy ingress of water together with abnormal over-break was encountered in this section. The anticline fold is suspected roughly along the Mahumangat Nallah. This is indicated by variable dip of rocks along both banks of Nallah. However this fold is located away from the tunnel alignment.

5.2 Subsurface Exploration by Drill Holes

In total 9 boreholes (4 deep and 5 shallow) were drilled along the tunnel alignment. Most of these boreholes have been drilled upslope of the alignment. Core recovery varies from 0-99% and RQD from 0-95%. The Q value of phylittes, quartzitic phylite of the formation varies between 0.33 to 0.83. RMR of phylittes, quartzitic phylite varies from 33-37.

5.3 Standard Penetration Tests

SPT's have been carried out in the drill holes along T-74R alignment. The soil recovered from the boreholes is generally hard, fine to medium grained silt/clay matrix with rock fragments. From 1.5 m-2.1m, 3.00 m-3.60 m and 4.50 m-4.55 m depth in BH-1, 'N' values recorded are 34, 47 and refusal to penetration respectively. In BH-2 from 1.50 m-1.70 m, refusal to penetration is recorded, BH-3 has recorded refusal to penetration from 1.50 m-1.55 m depth. In BH-4, SPT conducted from 6.00 m-6.05 m, 13.50 m-13.53 m, 34.50 m-34.55 m has recorded refusal to penetration.

Safe bearing capacity as per IS 1904-1961 for moist clay mixture that can be identified with strong thumb pressure is 15T/m^2 for soft shale, hard rock stiff clay in deep bed, dry

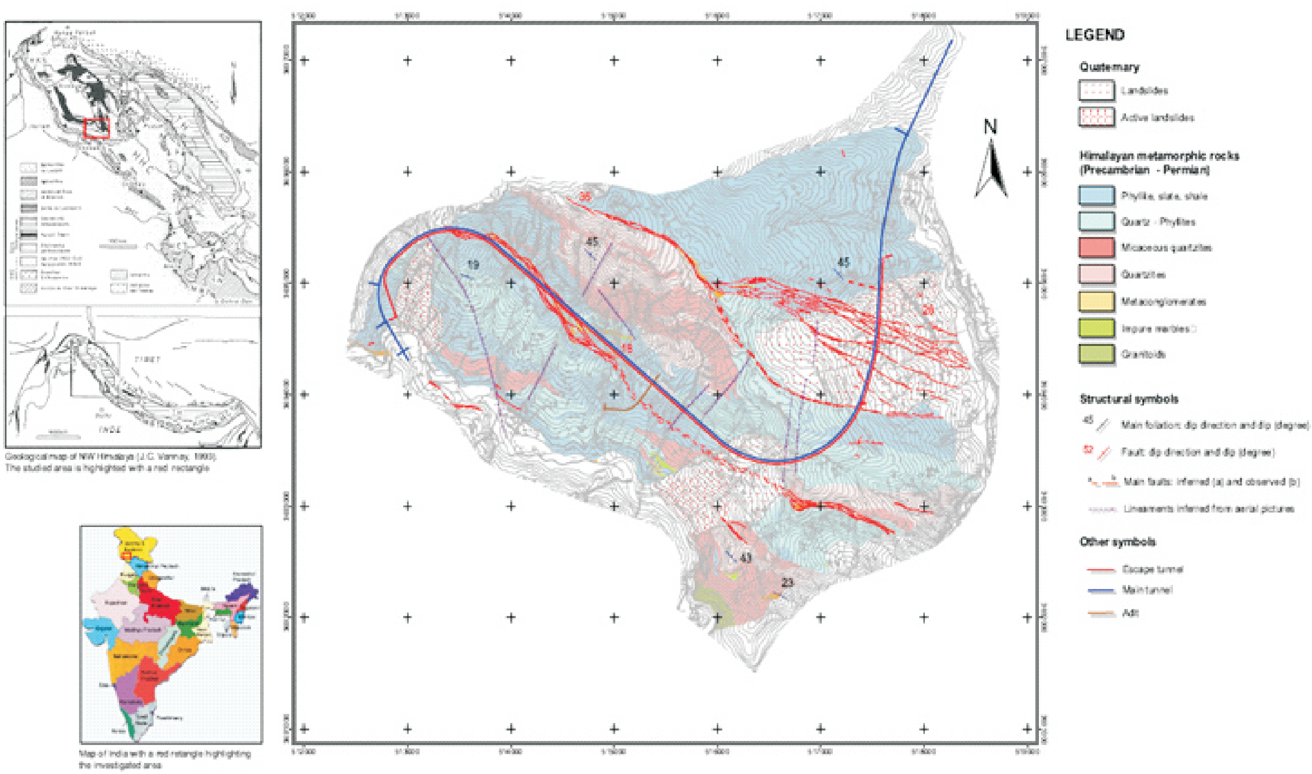

Figure 2. General layout plan of tunnel T74-R re-modified after IRCON Project NO:IRCON/1014/J and K. KQ/Consultancy T74R/178

is subject to ground conditions. Safe bearing capacity of soil ranges between 15T/m^2 and 45T/m^2.

5.4 Permeability Tests

Double packer's tests have been conducted in the northern end of the tunnel alignment towards Banihal, in BH-5A, BH-5B, BH-7 (Table 1). The tests have been carried out to determine permeability of the rock mass at different depths as per IS-5529 specification.

Conclusion

The tunnel alignment traverses through young Himalaya full of geological surprises and continuous changes as this area lies in thrust region. Tunnelling through this region is a major engineering challenge. The rock mass in Pir-Panjal range is highly heterogeneous hence NATM was adopted. Geological and geotechnical investigations were carried to decide the design criteria. The structures like folds, faults, foliated rocks were encountered along the tunnel alignment. The rocks along the tunnel alignment exhibit Tensile strength ranging from 10.5 kg/cm^2 to118.11 kg/cm^2, Point Load (KN) from 2.80 to 20.25, UCS from 60.80 kg/cm^2 to 3712 kg/cm^2, Modulus of Elasticity from 0.2331 to 1.587 kg/cm^2, Poison's ratio from 0.0765 to 1.0701, dry density from 2.164 to 2.966 gm/cc and permeability tests conducted on soil and rock sample yielded Lugeon values between 0.000 to 44.81. In order to understand the RQD, RMR, and Q value, boreholes were explored along T-74R alignment. From the borehole data, core recovery varies from 0-99%, RQD varies from 0-95% and Q value varies between 0.33-0.83 and RMR varies from 33-37 for poor rock classes.

Future Work

Railways are pioneers of tunnelling in India and future of tunnelling also belongs to the Railways. The Kashmir Railway link is likely to bring about socio-economic growth of the State of Jammu and Kashmir through improved connectivity within the province and with rest of the country. The project was envisaged to provide an efficient all weather transportation channel that could function in adverse weather conditions and reduce the travel time to various destinations in and outside the valley considerably.

Further, the design and construction of elongated and subterranean tunnels mainly those at enormous depth, is usually linked with a soaring level of risks due to a whole sequence of uncertainties mixed up, and the accomplishment of such tunneling projects depends very much on the proper selection of the support sections. A vigorous approach should be adopted for determining the most favorable method of construction for a long tunnel at great depth, based on the principles of risk analysis and multi-criteria analysis. Appropriate comprehensive investigations prior to excavation are a significant feature for the successful completion of the project and can be validated with the previous failures of the tunnel construction. Monitoring the slopes along the tunnel alignment and comprehensive monitoring inside the tunnel are also equally important for the excavation of tunnel.

Borehole	Depth (m)	Lugeon (n^0)	RQD	Test Section (m)	Lugeon (UL)	Classification	Lithology
			0	15-17.5	44.8	Turbulent flow	
5A	60.2	4	10	25-27.5	29.6	Turbulent flow	Phyllite
			20	45-47.5	22.9	Turbulent flow	
			22	55-57.5	21.0	Turbulent flow	
			32	10-12.5	0.0	Void filling	
5B	45	4	13	20-22.5	0.0	Void filling	
			10	29.5-32	20.1	Laminar flow	
			17	40-42.5	22.6	Wash out	
			5	40-42.5	26.2	Void filling	
BH-7	82.2	5	10	50-52.5	25.1	Void filling	
			0	60-62.5	17.2	Laminar flow	
			0	70-72.5	15.5	Wash out	
			25	80-82.5	13.8	Void filling	

Table 1. Shows the results of Double Packer`s tests carried on Bore holes 5A, 5B, &7

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