Long Highway Tunnels in Indian Himalaya under Construction

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ABSTRACT

Three long highway tunnel projects in realization in Indian Himalaya in states of Jammu-Kashmir and Himachal-Pradesh demonstrate rapid development of transport tunnelling in India. Until recently, hydro project tunnels dominated Himalaya tunnelling industry for last decades. Transport tunnels now in construction are being prepared and constructed in close cooperation with international contractors and experts bringing long&large transport tunnelling know how. First experience with excavation of three projects shall be presented with particular attention to the longest one, Patnitop Tunnel on Chenani – Nashri section of National Highway NH-1A from Jammu to Srinagar.

1 INTRODUCTION

In North-Western Himalayan state of Jammu and Kashmir, new single track railway line from Jammu to Srinagar is under construction with numerous tunnel sections. The longest tunnel of approx. 11 km under Pir Panjal mountain range has been successfully broken through in September 2011 as the first long transport tunnel in Indian Himalaya. Austrian Geoconsult was a lead partner of the JV for design and construction supervision.

Upgrade of National Highway 1A (NH-1A), from Jammu to Srinagar to a 4-lane highway has been prepared by National Highway Authority of India (NHAI) during last decade. Total costs are estimated to be 2.000 mil USD and travel time between the two cities should be reduced from 8-10h to 5-6h. The works started in 2011 on two most difficult sections of the alignment at crossings of two major mountain ranges of **Patnitop** (2.000 m above sea level) and **Pir Panjal** (2.850 m). Both sections are constructed according to DBFOT concession schemes with concession period of 20 years including construction time estimated for five years.

Rothang Tunnel under **Rothang** Pass (3.978 m) close to border between two Indian states of Himachal Pradesh and Jammu Kashmir is part of an all year road connection to remote areas of Ladakh on National Highway 21 (NH 21) between Leh and Manali. Project is based on Design-Bid–Build model with the Client Border Roads Organization (BRO) and tunnel excavation started in 2010.

All tunnels are constructed using principles of the New Austrian Tunnelling Method (NATM), excavation is done and foreseen mostly by drill&blast, shotcrete and rock bolts are used as a primary support and cast in situ concrete as a final permanent lining with waterproofing membrane in between.

Interesting feature is that all three tunnels have different concept solutions.

Figure 1 Projects Area

2 CHENANI – NASHRI (PATNITOP) TUNNEL – LONGEST ROAD TUNNEL IN INDIA

2.1 Project preparation and tunnel concept

Chenani Nashri (Patnitop) Tunnel is located between km 89 and km 130 of the existing NH1A road and is designed as a 9 km, single tube, 2-lane, bidirectional tunnel with parallel escape tunnel to be possibly widened later into a second traffic tube. Tunnel alignment is a result of alignment studies performed in 2004 – 2006 which presented different lengths of tunnel variants ranging from 1,2 km to 9 km. The Client NHAI finally decided for the longest "base" tunnel at elevation of approx. 1.200 m and with maximum overburden of 1.000 m. Tunnel was designed on a "DPR" (Detail Project Report) level including limited geotechnical investigation and evaluations, excavation and support definition, civil and structural design, conceptual E/M design, and corresponding specifications, BOQ and cost estimates. In 2010, tendering process for concession to design, build, finance, operate and transfer after 20 years was performed (DBFOT), and India-based group IL&FS Transportation Networks Ltd (ITNL) was awarded the concession. Concessionaire has chosen Leighton Wellspun Co. as a general contractor responsible for tunnel construction including short open road sections at both portals and complete E/M systems. Value of the Engineering, Procurement and Construction (EPC) contract is approximately US$570M on a lump sum, fixed price basis. Contractor's detail designer is Italian Geodata Co. and specialized tunnel consultant D2 Consult Prague.

Tunnel concept as defined in DPR stage remained unchanged (see Fig. 2) with potential for construction of the second tube later.

2.2 Start of the tunnel excavation and first experience

The tunnel construction started with excavation of portal cuts, particularly difficult at squeezed conditions of the north portal in spring 2011. First blast for tunnel was performed in August 2011 at the south portal, with an escape tunnel advancing ahead of main tunnel. This idea was accepted in DPR stage and geotechnical information from escape tunnel should serve for short term prediction of conditions in the main tunnel tube and for corresponding adjustments of excavation and support works.

First months of tunnel excavation are used for optimization of the work routines, meeting quality requirements, training of personnel and establishing of necessary site facilities rather then for maximum progress. This approach is reasonable considering estimated tunnel construction time of more than 3 years. At the end of November 2011 all four tunnel drives have already started and reached following distances:

South:	Main Tunnel 200 m	Escape Tunnel 350 m
North:	Main Tunnel 100 m	Escape Tunnel 140 m

Possible break through can be expected in 2014 if there are no unexpected conditions encountered and scheduled progress of tunnelling works is realized. Geotechnical concerns are high overburden, high and possibly unusual stress conditions, water ingress, water pressure and fault zones. Ground consists of uniform flysh sedimentary rock layers all over tunnel alignment and there is no comparable example of tunnelling in the area. Excavation of first meters experienced layers of competent, jointed sandstones and siltstones and very little water (dry season, low overburden). Over-excavation is due to blocky structure quite high and excavated profile rough. Excavation and support classes are designated A, B and C with subdivision in each, maximum round length 3,5 m, thin shotcrete layer, 5 m rock bolts and no lattice girders in class A and shorter rounds and stronger support in classes B and C. Deformation measurements are showing expected behaviour with slightly asymmetrical pattern due to prevailing inclination of bedding planes and values of max. several cm. It is assumed that design of support shall be adjusted as tunnelling experience is gained.

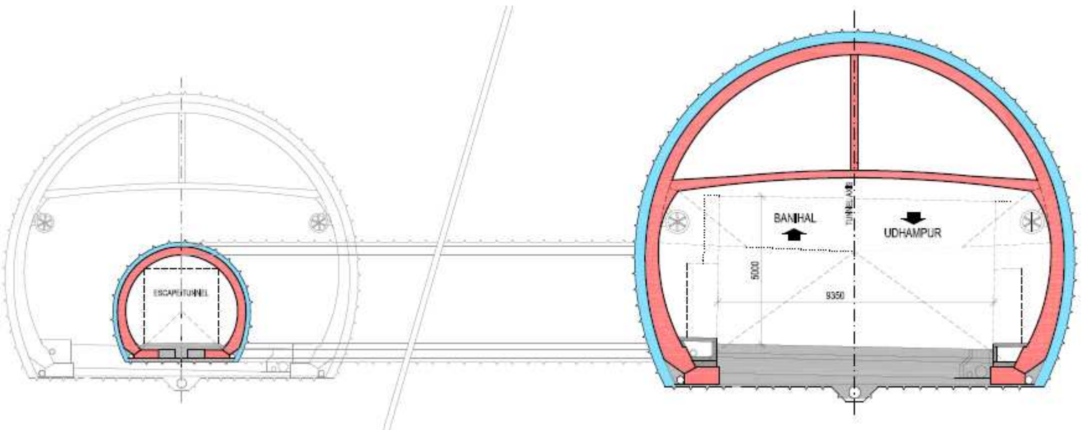


Figure 2 Tunnel cross section (DPR) and safety concept with foreseen possibility of future extension to a double lane, unidirectional tunnel

Figure 3 South and North portal of the Chenani-Nashri tunnel under Patnitop Pass (October 2011)

2.3 Geology, NATM and contract conditions

Knowledge about geological conditions comes from limited investigation during DPR phase, limited investigation during pre-construction period and from general information about regional geology. Project area lies in Western Himalaya in a belt called sub-Himalaya and tunnel crosses “Murree” formation of lower tertiary sediments of materials eroded from the high mountains. This belt is on the North framed by the Main Boundary Thrust dividing sedimentary formations from metamorphic complex. The whole tunnel length goes through one sedimentary formation composed by repetitive series of sandstones, siltstones and claystones.

NATM belongs to the group of “observational” methods in geotechnical engineering and as such is capable effectively manage very different conditions encountered during tunnelling. Optimum use of the method can, however, be achieved only with corresponding contractual and organizational arrangements.

Concession project, in particular for tunnel construction in a pure design&build (DB), lump sum contract form, is generally considered as having higher risk potential than standard contractual arrangements (design-bid-build, unit price contract). Keeping tunnelling works on acceptable risk level will need high competence and cooperation between involved parties (contractor and supervision) during the whole tunnel excavation period.

3 PIR PANJAL ROAD TUNNEL

Pir Panjal road tunnel is located between Banihal (direction to South-Jammu) and Quazigund (direction to North-Srinagar) on NH-1A road and has been prepared in DPR phase as a 8,45 km, single tube, 2-lane, bidirectional tunnel with an escape channel under the carriageway. This concept was changed (Figure 4) by concessionaire and approved by the client NHAI during detail design stage to a two tube, one traffic lane, single directional concept, with cross adits for escape possibility into other tube in case of fire or emergency. Concessionaire for the project is Navayuga Engineering Comp. Ltd and Austrian Geoconsult is their designer.

The Geology of the Pir Panjal mountain range is known from previous investigations and construction of Pir Panjal Rail Tunnel. It includes the complete Cambro-Trias Sequence with a mixture of very hard (UCS between 100 and 160 MPa) and moderately to hard rock strata UCS is between 40 and 80 MPa). Hard rock types include andesite / basalt, quartzite, silicified limestone and agglomerates while the moderately hard rock types include limestone, shale, agglomerate shale and tuff. The basic tectonic setting of Pir Panjal range in the area of tunnel alignment is dominated by a folding structure leading to different dipping directions on both sides of the range. The medium steep (60° to 70°) NE dipping of bedding planes on the southern part become steeper towards the main range while on the northern part flat to medium steep (35° to 40°) dipping towards SW is dom inating. The central areas show a distinct folding. Contact zones between rock units are often faulted. Bedding of rock is striking sub perpendicular to tunnel axis. Variable water conditions are expected.

The project will benefit from the fact that there is the same designer (Geoconsult) who did design and supervision for the rail tunnel crossing Pir Panjal range in close distance from road tunnel and at slightly lower elevation.

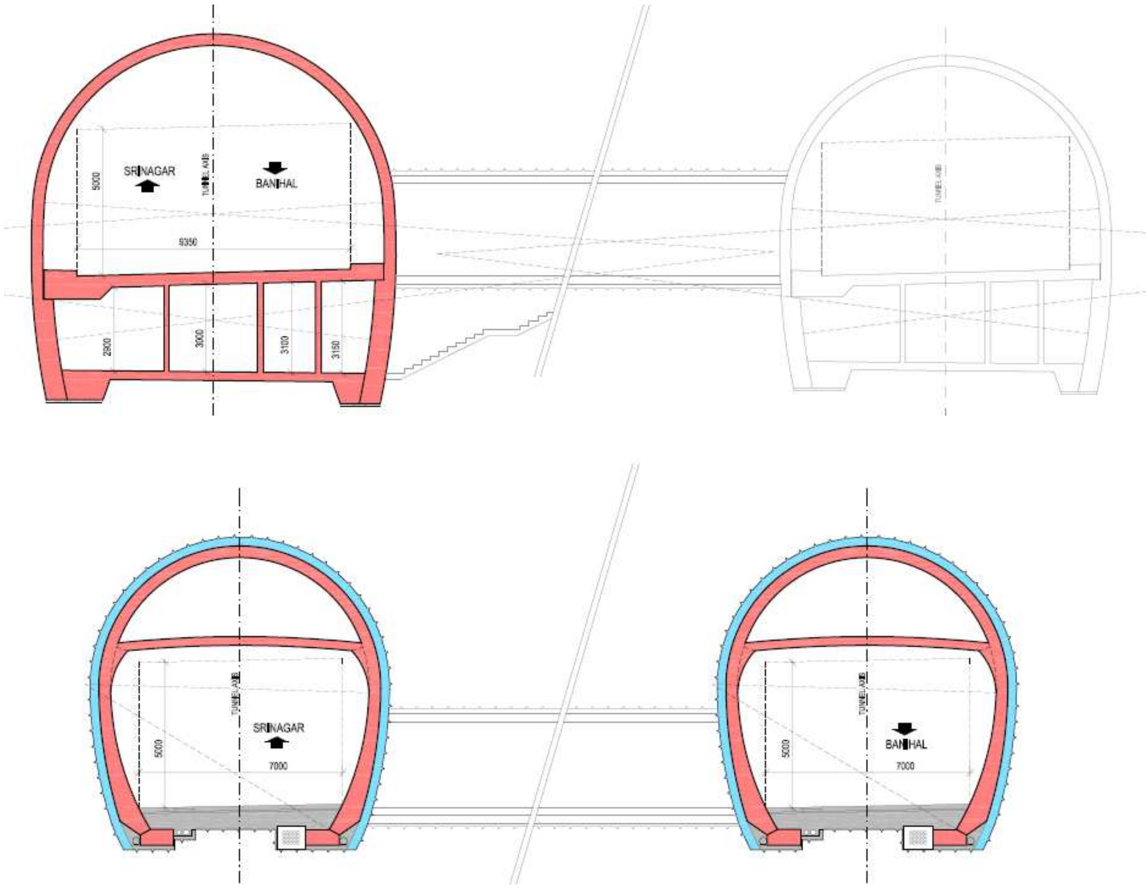


Figure 4 Development of the concept solutions for Pir Panjal road tunnel (above DPR solution, bellow concessionaire solution)

4 ROTHANG PASS ROAD TUNNEL

Rothang Pass road tunnel project is located on Manali – Leh road in Himachal Pradesh as a 8,8 km, single tube, 2-lane, bidirectional tunnel with an escape channel under the carriageway. Tunnel is located at elevation of more than 3.000 m with max. overburden almost 2.000 m. Project is based on Design-Bid–Build model and the Client BRO (Border Roads Organization) has awarded construction of the tunnel and approaches to SAJV (Strabag-Afcons JV) in 2009, tunnel excavation works started in 2010, and the tunnel should be completed at the end of 2015. The cost of building the tunnel and roadway amount to about US$350M. Designer is Australian SMEC, Independent Engineer (IE) for the project is Austrian D2 Consult International in JV with Indian ICT, and Proof Checking Engineer is Austrian 3G company. Tunnelling works are progressing from both portals, at the end of November 2011:

South tunnel drive 1.700 m
North tunnel drive 700 m

The northern portal will not be accessible during the winter months, therefore the main tunnelling works will be carried form the southern portal. Considering the high mountain climate and access possibilities for supply, Rothang tunnel is definitely coping with the most difficult conditions of the three mentioned long tunnels.

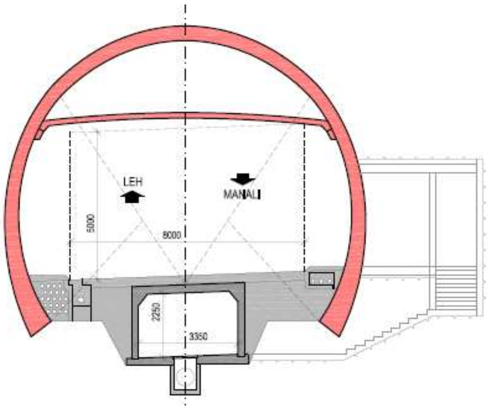


Figure 5 Concept solution for Rothang Pass road tunnel

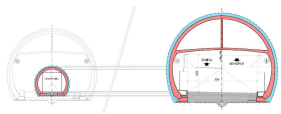
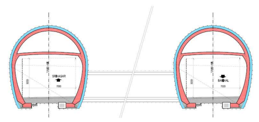
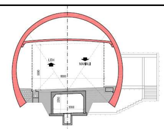
The rock at the site consists mainly of slate and migmatite with three potential fault zones and squeezing rock in some places. The New Austrian Tunnelling Method (NATM) with drill&blast technique is used for excavation and support installation as it can be flexibly adapted to different encountered conditions.

5 SUMMARY

In the moment, there are 3 very long road tunnels under construction in Indian North-West Himalaya with expected excavation periods of 4 – 5 years, to be broken through in 2014. All tunnels are on important transport routes and when finished they will improve accessibility of Indian Himalaya border areas. International contractors and consultants are involved in all projects and according to recent progress; it seems to be realistic to finish all projects according to schedules and expectations.

Different tunnel concept solutions have been developed and adopted, demonstrating that there is no universal solution for tunnels of similar length. Different local conditions as well as different experience and expectations of involved parties (client, designer, contractor) lead to different solutions still satisfying basic requirements of technical construction feasibility and operational safety. Objective evaluation and comparison of used concepts can be done only after tunnel construction is finished and operational experience gained. In the moment, following comparison of chosen concepts is base on general understanding:

Table 1 Comparison of tunnel concepts

	 Chenani – Nashri (Patnitop)	 Pir Panjal	 Rothang
Construction Costs	0	-	+
Construction Logistics	+	+	-
Geotechnical Problems	0	+	-
Possibility of future 4-laning	+	-	-

Advantage +
Disadvantage -
Neutral 0

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