CONSTRUCTION OF ATAL TUNNEL

N. Rajesh Goud
MTech Student, Geotechnical engineering, Department of Civil Engineering,
Jawaharlal Nehru Technological University, Hyderabad

ABSTRACT
Atal tunnel is the world's longest highway tunnel at an altitude of about 10,000 feet from the Mean Sea Level (MSL). It was formerly known as the Rohtang tunnel and was renamed after India's former prime minister Atal Bihari Vajpayee. The length of the tunnel is 9.02 Km. It is also the longest bi-directional, single tube roadway tunnel of India and a project of great strategic importance. It is built with modern technologies and specifications in the Pir Panjal Range of Himalayas. The construction method for this tunnel is based on the philosophy of NATM. During construction of this tunnel, the team faced many challenges, unexpected difficulties like sudden collapse, ingress of water from pores of rocks etc. The team overcame such difficulties by solving the challenges using different methods.
This paper will briefly give an overview of the strategic importance of the tunnel, geology of the site, construction technologies implemented, challenges faced during constructions and how the team overcame those.

Keywords: Atal Tunnel, Construction Technologies, Challenges, Geology

INTRODUCTION
India's mega tunnel project, Atal Tunnel is constructed in highly tectonic and young Himalayan mountains. The client of this project is India's Border Road Organisation (BRO), which is responsible for construction and maintenance of Indian road network in border areas and friendly neighboring countries. This project is taken over by a joint venture of Strabag-Afcons for India's Border Road Organisation. India's Ministry of defence and Border Road Organisation engaged SMEC Consultants, India to provide engineering, design and advisory services for the project.
The foundation stone for this project was laid in 2002, by India's former Prime Minister Shri Atal Bihari Vajpayee. Construction of the main tunnel commenced in 2010, by doing the first blast at the south portal of the tunnel. Nearly after a decade under construction, the tunnel was completed despite many challenges like avalanches, heavy snowfall, and harsh geographic conditions. It was dedicated to the nation on 03 October 2020.

CONSTRUCTION FEATURES OF TUNNEL
The tunnel is horse-shoe shaped, having a roadway of 10.5m, with carriage way width 4m. Footpath of width 1m on either side of the road and a median of 0.5m width are provided. In case of any casualty, an emergency escape tunnel is provide with size of about 3.5m * 2.25m, which is constructed below the pavement. Emergency passages are provided at every 500m interval and turning cavern of 2.2m. Design speed of the road in the tunnel is 80km/hour. Emergency provisions like fire hydrants, telephones, air quality monitoring systems and CCTV cameras are also provided.

GEOLOGY OF THE SITE
The Himalayan ranges consist of complex geology and many geological uncertainties. Hence, it is essential to know the rock nature along and around the site before construction of such a major structure. The tunnel passes through complex formations and intermixed rocks were encountered along the alignment of the tunnel.

Rock Types: From the south portal of the tunnel Phyllite, quartzite schist rocks were encountered and from the north portal Migmatite gneisses, mica schist, quartzite was encountered often. The value of Unconfined Compressive Strength (UCS) of the rock samples collected ranges between 17.8 Mpa (minimum) and 105.3 Mpa **(**maximum) with an average value of 61.6Mpa [2]. As the region is covered by snow almost half of the time the porosity is found to be moderate to high. This indicates that there is a possibility of heavy water ingress during construction.

Foliation: The tunnel passes through numerous joints and shear zones. The main foliation of the rock was found creating an angle of 60^0 with the tunnel axis. As the tunnel axis is not parallel to foliation, it is considered a favorable condition.

Faults: The geological mapping of the field is done by surface traversing along the accessible slopes and by remote sensing across inaccessible areas. Through this study major tectonic structures were identified like Seri nala fault, Chandra kothi fracture zone, Rohtang ridge fracture zone.

Seismic Factors: The tunnel is located in a high seismic zone (Zone 5). Looking into history, there are no such seismic casualties in the previously constructed structures in this region. So no special provisions were provided against seismicity.

CONSTRUCTION OF THE TUNNEL

Rohtang tunnel construction is based on the NATM strategy. NATM works on the principle of continuous observations made after each execution cycle. As the Himalayan range has varying geological conditions this is the best suited methodology for construction of the tunnel.

NATM can be defined as a support method or philosophy to stabilize the tunnel perimeter with the help of anchors, spraying of concrete and other methods of supporting and controlling stability by regular monitoring. The main principle of NATM is that the surrounding rock provides main support to the tunnel excavated and additional support if needed is provided to maintain the strength of rock and prevent disintegration [4]-[5]. The surrounding rock itself therefore behaves as a structural arch which acts as a load bearing member. So this method is suitable where the ground or rock has high strength and this strength must be maintained. The lining technique utilized in this method is thin sprayed concrete (shotcrete) lining and in case of requirement of any additional support, it is provided by other means like anchors, steel reinforcement, girders.

According to the information in Technical Brochure Atal Tunnel, by Border Roads Organization, construction of the tunnel is started from both south and north portals simultaneously. Initially a series of activities were carried out to create the opening of the tunnel before the subsequent main tunneling activities started. The series of activities carried out are "drilling of holes, loading of explosives, shooting explosives, clearing muck, installing initial tunnel support" [2].

The main tunneling and construction activities were organized and carried out as under:

a) Top heading and half sided benching: The top heading (or upper half) of the tunnel section is excavated first and supported by shotcrete (sprayed concrete lining) and benching (lower half) follows.
b) Deep invert excavation: Excavation for lowest section of tunnel i.e., floor. Section of excavation is shown in the Fig 1 below.

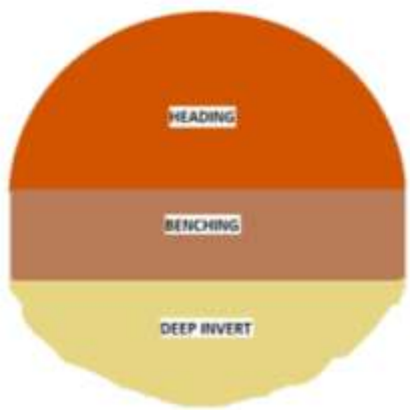

Fig 1: Section of Atal tunnel excavation

c) Main tunnel drainage is provided and concreting is done on egress tunnel (outlet) base slab
d) First lining kicker concreting
e) Precast emergency egress structures installation
f) Pavement drainage and pit installation works
g) Second lining kicker concreting and backfilling upto road level
h) Cable ducts installation and concreting base of walkway
i) Final arch concreting over lining and ventilation slab reinforcing and concreting
j) The road is constructed by pavement quality concrete with dry lean concrete laid as base
k) Kerb installations and walkway (footpath) works
l) Safety installations, Electrical works and finishing works
m) Storage caverns for fire water and turning bay caverns

CHALLENGES IN ATAL TUNNEL CONSTRUCTION

Due to the presence of many geologic structures, sudden tectonic activities tunneling in the young Himalayan Mountains became challenging. The team faced many unforeseen activities during the construction and overcame them by adopting different methodologies and techniques. Following are some challenges came up during Atal tunnel construction:

Seri Nala fault zone: This is the longest shear zone ever encountered in a single stretch, approximately 587.5m in any tunnel construction. The tunnel is passing under Seri Nala, because of which weathering of rock occurs, muck along with water started to flow from the face. Heavy inflow of water at a rate of 8000 litres per minute was experienced. So, while tunneling through this zone, the team faced many unexpected difficulties and overcame them using various solutions based on the condition at that place.

1. Plugging with sandbags, applying a thick layer of shotcrete is done to control the muck flow in the tunnel. Then a hole at the centre of the face, two more holes at some distances were drilled about 10 to 20 m depth. These holes provide information about the upcoming soil or rock strata while heading and also provide drainage for water flowing.
2. Certain holes are provided in the crown region for pressure relief and drainage purposes, so that water can be channelized and removed.
3. Umbrella of perforated pipes is provided while advancing with excavation to provide support and strength to the roof.
4. Pre-grouting is done through the previously drilled holes with OPC and micro fine cement through a reasonable pressure as required depending on location. As the pipes in long holes are perforated, the grout spreads evenly and creates a thick cement layer at the crown.
5. Area supported in such a way is excavated slowly and closely spaced steel ribs are utilized to support the excavated part for further advancement.

In this way the Seri nala fault zone became a biggest challenge to the team and it took almost 4 years to cross this 600 m fault zone.

High overburden at North Portal: Overburden was high from the beginning itself and the tunnel is passing through rock formations composed of metamorphic migmatite. Main challenge encountered is due to high stress conditions and resulting pressures due to surrounding rock. During excavation due to sudden release of stresses rock were prone to exhibit rock bursting and rock squeezing around the periphery of opening. Even delayed release of stress along these planes caused problems like cracks in lining, excessive stress on rock bolts and bending of rock bolt plates. This varied behavior of rock brought new challenges in front of the team.

Therefore, such behavior of rock is regularly and accurately monitored and these problems are encountered by taking necessary measures using Lining stress controllers (LSC) and SLOTs [1].

Sudden collapse of tunnel: While construction, the tunnel roof of 50m stretch suddenly collapsed and fortunately it didn’t cause any loss of life. This caused a hindrance in the progress of work.

Various measures were taken to avoid collapse of tunnel like rock bolting after clearing muck, rock bolting with wire mesh and shotcrete were done monolithically, continuous monitoring of deformations and deflections, piped roofing to take high overburden [7].

Ventilation building: The installation of the ventilation building at South Portal became a very challenging task as it is located in a landslide region. Constructing of the building in a stable deep rock cut, anchoring walls of the ventilation buildings to arrest movement of building and providing measures against sliding of slope like anchoring after removing loose cover from the slope, providing an avalanche gallery.

Even at the north portal installation of the ventilation building has been challenging as there is no sufficient space available and must be built along the slope. This slope is in a high avalanche prone area. Finally the building was constructed in a straight alignment along the tunnel on a raft foundation in a safe zone devoid from avalanche.

Alignment precision while progressing: Construction of the tunnel was carried out from two ends simultaneously. Electronic total station survey instruments were used for the purpose of alignment of tunnel. Due to their magnetic nature, they were getting affected because of huge support installations made of steel as the tunneling is being progressed. Inertial precision technology (gyro-meters) is used to counter after every one km of excavation.

In this technology, the gyro meter measurement not only gives sensors positions but also provides information about orientation of sensors [6]. Hence positioning and orientation are inherently linked in this inertial sensor technology.

Accessibility constraints to site: Transportation availability to the site is not a smooth process in this young Himalayan region. Many challenges are faced during material transportation and this somewhat added to the delay in work execution.

Extreme weather: Rohtang valley region remains inaccessible due to heavy snowfall nearly 6 months; as a result construction work can be carried out only for 6 months in one year. Therefore the project implementation got hindered and delayed.

Due to extreme cold conditions at site workers were also having bad effects on health. Medical aid is provided accordingly.

Communication problems: Due to remoteness of the site and extreme weather conditions like snowfall no proper network is available and wireless communication through radio is not possible. So installing cables is the only option which is done with the help of BSNL.

NECESSITY AND STRATEGIC IMPORTANCE

The tunnel is constructed across Rohtang Pass on Leh-Manali highway, Kullu district in Himachal Pradesh. This tunnel is a best alternative for the traditional route between Kullu and Lahaul Spiti valley, which is considered to be one of the dangerous routes in India, as landslides are common in this region. The Rohtang pass region faces heavy snowfall and avalanches for about half a year, and the road remains closed, due to which people in Lahaul and spiti valley lose connectivity with the rest of the country. This tunnel provides all weather connectivity, saves 46 km distance and 4 to 5 hours of travel time. It is also considered as strategically important for Indian defence forces due improved connectivity and reduced travel time.

CONCLUSION

“No matter what you are going through, there is light at the end of the tunnel and it may seem hard to get to it but you can do it and just keep working towards it and you’ll find the positive side of things.” -Demi Lovato

The journey of Atal Tunnel construction involves a lot of surprises and new challenges at every. The team did not lose hope and overcame all the technical hurdles coming in the way and created history of constructing world’s longest highway tunnel at such a high altitude of 10,000 feet. Study of such constructions and the experience of the teams involved give ample knowledge, inspiration and ideas and paves way to more no of such engineering marvels.

REFERENCES

1) Border Roads Organisation (2021),"Atal Tunnel, Rohtang Available: http://bro.gov.in/WriteRead Data/linkimages/9390242669-t2.pdf
2) Border Roads Organisation(2021), "Technical Brochure Atal Tunnel, Rohtang".Available: http://bro.gov.in/WriteReadData/linkimages/4131323875-t1.pdf
3) Wulf Schubert, "Development and Background of NATM", Austrian Tunneling Seminar Ankara, Published date: April 1st, 2015, Available: http://www.ytmk.org.tr/files/files/01_TUG_NATM.pdf
4) Chapman. D, Metje. N, Stark. A (2010). "Introduction to Tunnel Construction" (1st ed.). CRC Press. https://doi.org/10.1201/9781315273495, (page 185-187)
5) Karakus, Murat & Fowell, R. (2004). "An insight into the New Austrian Tunneling Method (NATM)".
6) Conference: The 7th Regional Rock Mechanics Symposium, Sivas Volume: Sivas, Turkey, October 2004.Available: https://www.researchgate.net/publication/258224136
7) Manon Kok, Jeroen D. Hol and Thomas B. Schön (2017), "Using Inertial Sensors for Position and Orientation Estimation", Foundations and Trends in Signal Processing: Vol. 11: No. 1-2, pp 1-153. http://dx.doi.org/10.1561/2000000094
8) Ravi Panwar(editor), "Atal Rohtang Tunnel- Construction of the World's Longest Highway Tunnel at 10,000 feet"
9) Website: theconstructor.org. Available: https://theconstructor.org/case-study/atal-rohtang-tunnel-construction-of-the-worlds-longest-highway-tunnel/95419/