AN INNOVATIVE APPROACH FOR CONSTRUCTION OF LARGE ADIT THROUGH RIVER BORNE MATERIAL AT VISHNUGAD PIPALKOTI HYDRO ELECTRIC PROJECT (444MW), UTTARAKHAND, INDIA

D.V. SINGH, R.K. VISHNOI, GAJENDRA SINGH, AJAY KUMAR, N.K.OJHA AND P. VISHWAKARMA

THDC India Limited, Rishikesh, Uttarakhand, India

ABSTRACT

Vishnugad Pipalkoti Hydro Electric Project (VPHEP) is a run of the river scheme, located on river Alaknanda, spanning between Helong and Birahi Villages in Chamoli district of Uttarakhand, India. The Project envisages construction of 65m high Concrete Gravity Dam, three nos. underground Desilting Chambers of 390m length each, 13.4 km long circular Head Race Tunnel (HRT) of 8.8 m finished diameter (12 km by double shield Tunnel Boring Machine-TBM) etc.

In order to facilitate the start of excavation of HRT through TBM, an entry adit of diameter 9.95m and a chamber of diameter 12 m for launching the TBM are being constructed through huge deposits of River Borne Material (RBM) and slope wash material (debris). Construction of this large adit and large launching chamber by non-blasting, pre-strengthening and multiple drifting methods etc. through RBM is a unique example of engineering in the Himalayan region. Challenges during execution intensified in monsoon season due to massive water seepage laden with silt (being the RBM as tunnelling media) in entry adit to TBM.

This paper briefs about the art of engineering for designing, construction and tackling of complex geological circumstances encountered during construction of such a large adit. The adit 55 m in length, part of which will act as launching chamber (17.5 m length) for TBM has been constructed successfully.

1. INTRODUCTION

THDC India Limited (THDCIL), a joint venture of Govt. of India & Govt of U.P., have taken up the implementation of VPHEP with an installed capacity of 444MW (4x111 MW) on river Alaknanda in the state of Uttarakhand, India (Figure 1) with World Bank financial assistance. The purpose of the VPHEP is to harness the energy of the Alaknanda river for Hydro Electric Power generation as a part of Integrated and efficient development of Hydro resources of Bhagirathi

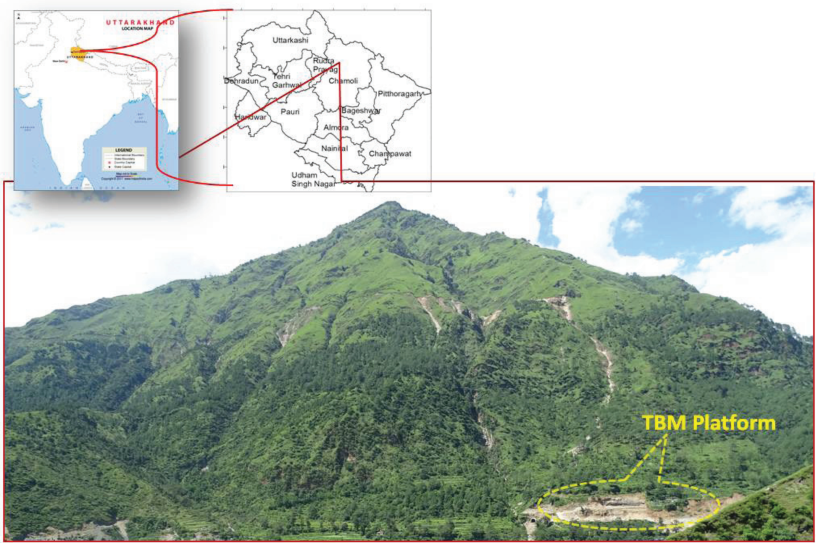

Figure 1 : Location Map of TBM launching platform of VPHEP

and Alaknanda rivers and their tributaries. The project utilizes a gross head of 237m to generate 444 MW of power. The water conductor system consist of three intakes and sedimentation chambers and then a 13.4 km long HRT of 8.8m diameter of circular shape. The excavation of 12km long HRT shall be done with TBM method and 1.4 km length of HRT is being excavated by Drilling and Blasting Method (DBM). TBM is planned to enter from upstream side of the powerhouse complex towards the Intakes (i.e. from the Pipalkoti dolomites to the Gulabkoti quartzites) through an entry Adit of 632m length.

2. GEOLOGICAL SETUP OF PROJECT AREA

The project is located in the tectonic window known as Pipalkoti Window (Carbonate suite of Chamoli) exposing Lesser Himalayan metasedimentary rocks enveloped by low to medium grade metamorphic rocks of Higher Himalaya. The Higher Himalayan crystalline rocks thrust over the Lesser Himalayan rocks along a major tectonic shear known as the Main Central Thrust (MCT) Zone. The rocks of window zone are grouped under the Garhwal Group represented by low-grade quartzitic sandstone, dolomitic limestone and slates with metabasic sills and dykes. The rocks of the project area are folded in a wide open regional domal structure known as the Pipalkoti Anticline, which is intersected by a number of faults complicating the structural setup. The most important thrust/ faults are those that dissect the rocks of Pipalkoti Formation lying in the core of the structure: namely the Tapon Thrust, Bemru and Hat Faults. Towards the Intake, the Gulabkoti Formation has thrust over the Pipalkoti Formation along the Gulabkoti Thrust. On the south-western side, this formation has a faulted contact with an overriding crystalline thrust sheet locally known as Jaisal Fault.

Although, Power House area is situated in Pipalkoti Formation of Garhwal Group consisting of slates, alternate bands of slate & dolomite with different set of discontinuities and folding within the Pipalkoti Formation. However, TBM Adit to HRT is located on a river terrace at the right bank of Alaknanda river (upstream of Harsari Nala) at El. 1152.5 m. TBM platform and the slope above the TBM platform are covered by huge deposits of RBM and slope wash material (debris). The RBM is generally showing graded material consisting silt to boulders of up to 2 m. Most of the upper surface of the slope wash material had hardened due to calcareous solution activity. The calcareous leaching from upper reaches of dolomitic limestone solidifies the upper surface of the debris/RBM and it shows pseudo-rock behavior, and it is termed as 'Consolidated RBM' (Figure 2). It is worth to mention here that, on the back slopes above the TBM platform (El. 1152.5 m) there is 1.5 to 2 m thick layer of silt/ mud, sloping in the downstream direction. This layer was wet during summer also. In u/s slope end of TBM platform (± 165 m from TBM Adit) it is at EL 1164 m, while at TBM entry adit it levelled at EL 1157 m. There is no rockmass exposed in the TBM platform area (± 350 m length). Rocks are exposed in the adjacent nalas area which is ± 200 m away from TBM adit.

In order to assess the subsurface condition along TBM Adit, Geophysical exploration by Seismic Refraction method was performed by National Institute of Rock Mechanics (NIRM). Resistivity Imagine survey had been done by Geophysical team of NHPC to explore the rockmass condition up to 200m along the entry Adit of TBM. An Exploratory Drill Hole of 104m depth had also been done from surface at RD 217m of Adit to ascertaining the rockmass conditions along Adit.

During construction of Adit, RBM has been encountered at the beginning of excavation in heading portion. Sandy silt layer was encountered at the invert level after RD 10m and this sandy silt layer was gradually increased towards the crown portion and it reached crown portion at RD 41m. Afterwards, the face is completely covered by sandy silt layer. This sandy silt layer is damp to saturated in ground water condition. During monsoon the seepage of water has been measured upto ~200 litre / minute from the right side of the Adit.

632m long TBM entry Adit to HRT shall be driven through RBM/Slope wash material uo to RD 200m followed by Slate, interbedded sequence of slate and dolomitic limestone. Considering the huge extent of RBM / debris, it is planned to excavate remaining length of Adit (beyond RD 55) by TBM itself.

3. DESIGN OF SUPPORT SYSTEM

Construction of larger dia. tunnel is always a challenging task in the Himalayan region. Here at VPHEP, Adit of 12.75m diameter which is initial part of entry of TBM and launching chamber have been constructed through RBM / Slope Wash Material. This construction was possible due to steady rock support system analyzed and installed during construction of Adit. The densification of the strata indicates that the strength and deformation parameters may be more but for conservative design, the analysis and design for the TBM adit had been carried out on the parameters mentioned in Table 1.

Table 1 : Geotechnical Parameters for design

Parameters	Unit	Values
Saturated Unit Weight	[kN/m3]	20
Friction Angle	[phi°]	27
Cohesion	[MPa]	0.075
Deformation modulus	[MPa]	250

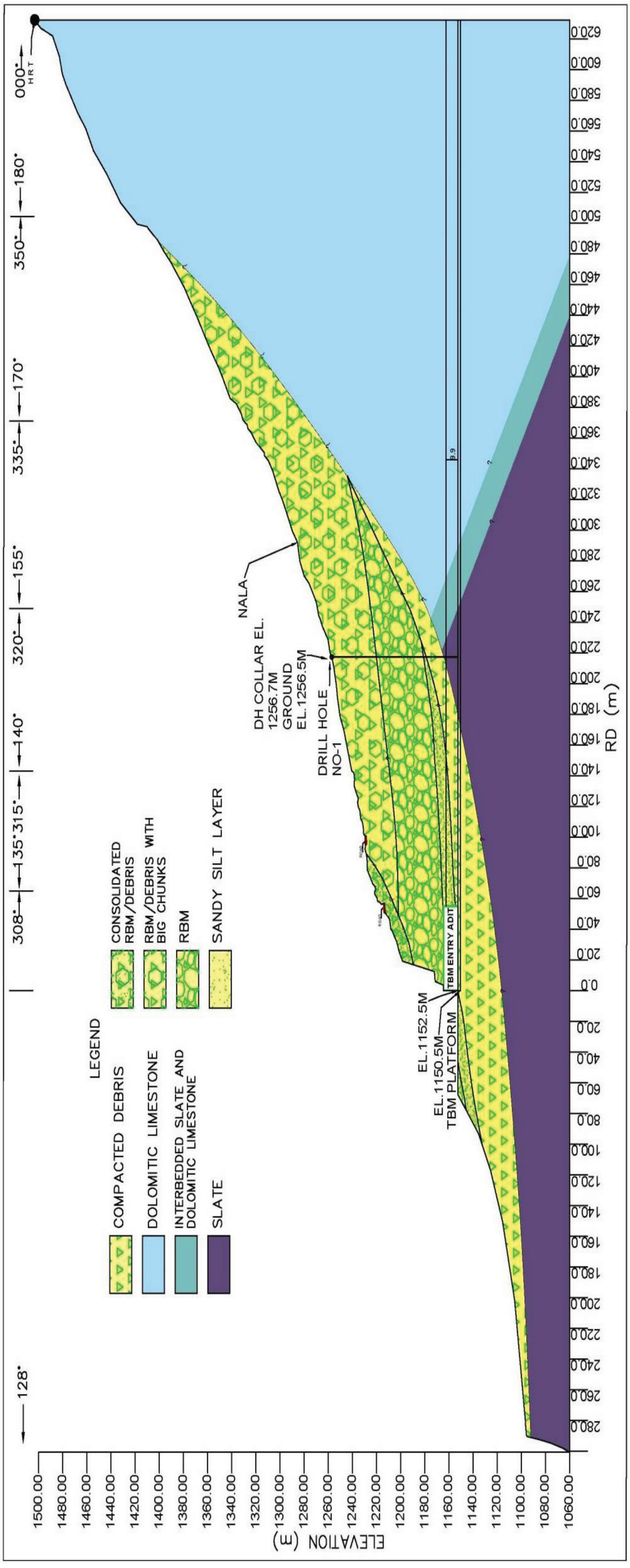

Figure 2 : Geological Section along TBM Entry Adit

To simulate the tunnel advance excavation or for softening of tunnel, the Modulus value of 75 MPa (30% of Original modulus) had been used in analyses. For the stability analysis, vertical load corresponding to the maximum vertical cover above the tunnel (50 m) is considered in the analysis. The analyses have been carried out for K=0.54 (Based on Jacky Formula) for estimation of horizontal stresses around the tunnel. Since, the river bed level is more than 80 m below the level of TBM platform, hence the effect of water table is not considered directly. However, the unit weight of overburden material is considered as saturated unit weight rather than the dry unit weight, to account for additional loading due to partial saturation during monsoon.

The stability analysis of the TBM Adit had been carried out using Finite Element Programme PHASE2 (Rocscience) by AF Consult, as a continuum model using Mohr-Coulomb yield criteria and stresses and deformations around the tunnel are estimated to check the stability of the tunnel. Following (Table 2) were considered in the analysis,

Table 2 : Consideration of rock support properties in design & analysis

Shotcrete Concrete strength = 25 MPa Modulus of Elasticity = 25 GPa Residual Compressive Strength = 5 MPa Tensile Strength = 3.5 MPa
Pipe roof Diameter= 114 mm Spacing @ 250 mm c/c Length= 12 m with overlap of 4 m and at an angle of 40 upward
Self drilling anchor (SDA) Diameter D = 32 mm Length L = 8 m Modulus of Elasticity E = 200 GPa Yield Capacity Fy = 28 t Design Tensile Capacity T = 16 t

In analyses the excavation is carried out in heading and stages of benching. Analyses indicate that the maximum total displacement values are 52 mm at crown, 29 mm at left wall, 29 mm at right wall and 62 mm at invert after complete excavation (Figure 3). The tunnel convergences (vertical and horizontal) after complete excavation are lower than that of 1% and the axial forces in the bolts are well within its design capacity. Hence the provided support system is adequate.

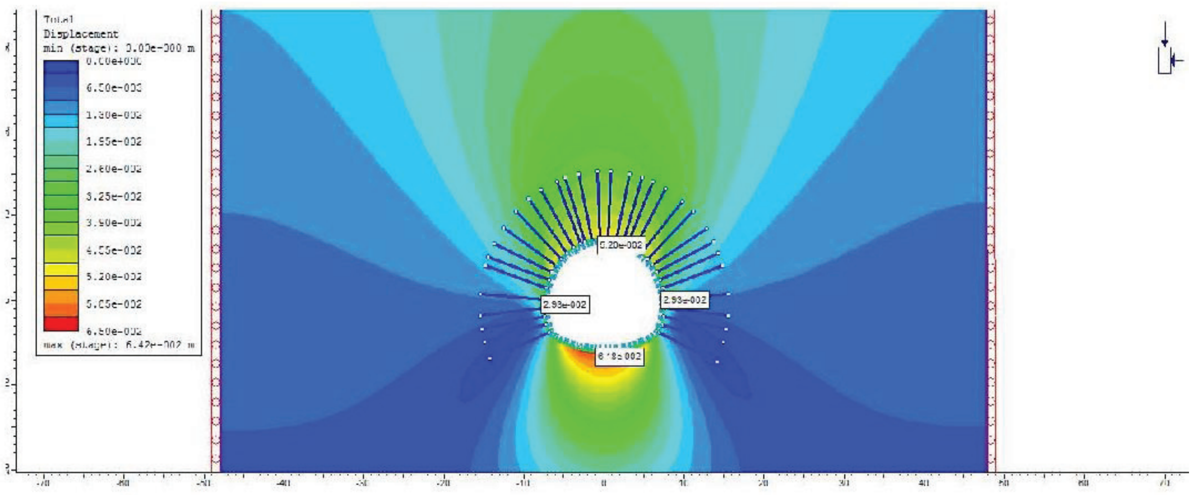

Figure 3 : Total displacement after complete excavation of TBM Adit.

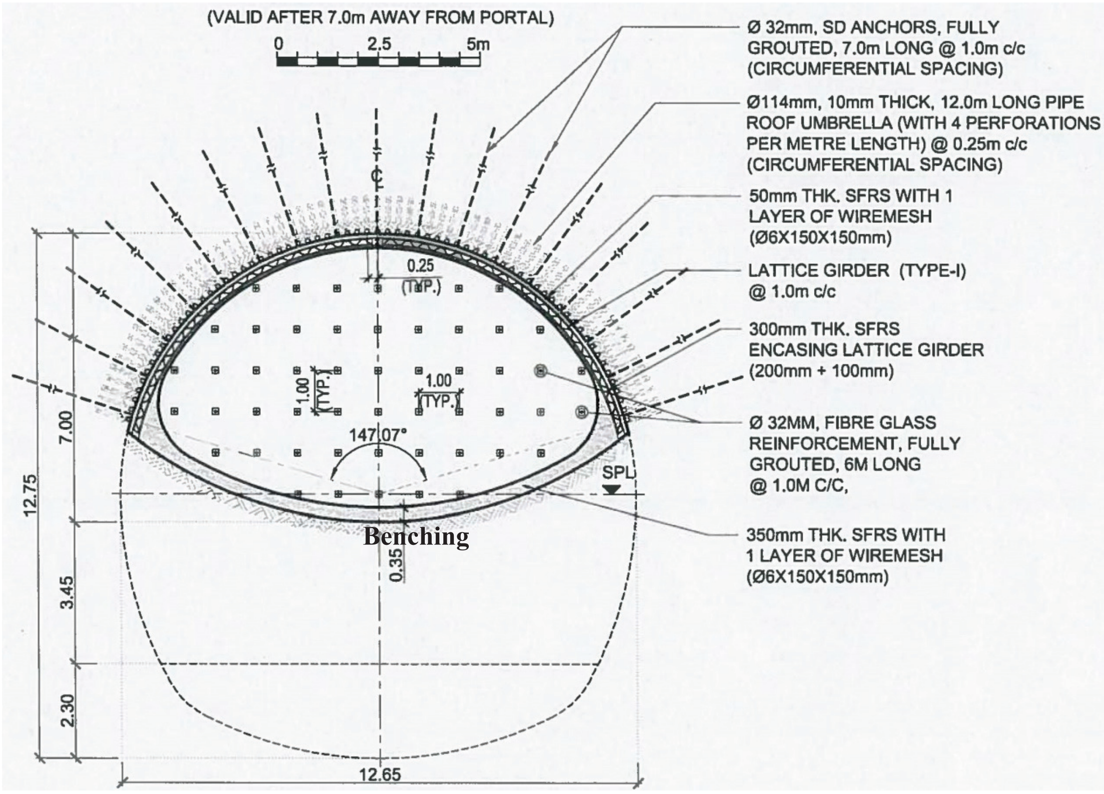

Figure 4 : Support system for TBM entry Adit.

Hence, based on the analyses, the support systems adopted for TBM Adit are Pipe roof umbrella of 114 mm dia. (perforated pipes), 10 mm thick, 12 m long with overlap of 4 m with next pipe roof umbrella @ 250 mm centre to centre at an angle of 4^{o} upward. The lattice girder 130x32x25 mm @ 1 m c/c along with 350mm shotcrete with fibres (Figure 4). The face confinement with 40 mm dia., fully grouted Fibre Glass Reinforcement, 6 m long @ 1.5 m c/c with 3 m overlap with next set of reinforcement.

32 mm dia., 8 m long fully grouted self drilling anchors (SDA) @ 1 m c/c in crown and walls after 7 m away from the portal location. For the tunnel stretch between portal and 7 m away, the length of the anchors kept as 4 m. The excavation cycle of 750 mm -1000 mm length had been considered as per site conditions for excavation and support system and only after supporting the stretch, the next cycle of excavation was undertaken.

4. CONSTRUCTION OF TBM ADIT

Before start of excavation of TBM entry Adit, it was necessary to stabilize the slope above and surrounding the Adit portal. This slope consists mainly of RBM and slope wash material. Slope surrounding the portal was treated by 100mm thick Shotcrete with one layer of wiremesh along with 12m long SDA of 32mm dia. @ 1.5m c/c. 8m long drainage hole of 76mm dia @ 4m c/c was also provided.

Excavation of TBM Adit (up to 55m) was done in sequence of different stages i.e. Heading at Stage I, Benching at Stage II and Invert at Stage III.

After stabilization of slope and portal area with pipe roofing for 12m length @ 0.25m c/c, mechanical excavation of Adit was started by excavator. Pipe roofing was repeated after every 8m excavation uo to SPL so that there would be always overlap of 4m for additional support. Face excavation of heading was done for 0.75m - 1m, followed by 50mm thick SFRS and installation of lattice girder along with different layers of SFRS (300 mm) and SDA (4m long for initial 7m reach then length of SDA was adopted as 7m). Existing face was strengthen by SDA and shotcrete in addition to pipe roofing. Strengthening of invert was also planned by 350mm SFRS with one layer of wiremesh. After advancement of heading up to 16 m, benching was started.

RBM had encountered at the beginning of excavation of TBM entry Adit in heading portion. Sandy silt layer was encountered at the invert level after RD 10m and this sandy silt layer was gradually increased towards the crown portion and it reached crown portion at RD 41m. Afterwards, the face is completely covered by sandy silt layer. This sandy silt layer is damp to saturated in ground water condition. During monsoon the seepage of water has been measured upto ~200 litre / minute (Figure 5) from the right side of the Adit along with immense quantity of Silt. In the upstream of TBM Adit, the higher slopes are highly water charged during monsoon and the water bearing layer is having downward gradient. At chainage 38m, sand lens embedded in RBM together with approx. 3 l/s of water probably created above the crown and in front cavity of approx. 5 m height which affected the Adit up to RD 26m. The cavity area treated by installation of steel ribs of ISMB 300 @ 0.5m. Entry TBM Adit has been constructed up to 55m including the launching chamber of 17.5m (Figure 6).

Figure 5 : Gushing of water with silt from right side at RD 41.5m of TBM entry Adit.

Figure 6 : TBM Entry Adit with Launching Chamber.

5. CONCLUSION

There is no rock exposure in the TBM launching platform area and the slope above the platform are covered by huge deposits of RBM and slope wash material or debris. TBM will be driven through RBM/Slope wash material followed by slate, interbedded sequence of slate and dolomitic limestone. 12m large entry TBM Adit has been excavated up to 55m for launching of TBM. This large Adit has been constructed to facilitate HRT excavation in stages with the help of various kind of support system and tackling of extreme condition during Monsoon which is a unique example of engineering in the Himalayan region.

REFERENCES

Annual Geological and Geotechnical report (no. 4) Vishnugad Pipalkoti HEP(4x111mw) for 2017-18.

Design report for stability analysis of TBM Adit, R-71.2754.05.306-rev 2 December 2015.

Geotechnical Baseline Report (GBR), VPHEP Version 6.2, THDCIL.