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Case Study on Water Ingress in Himalayan Tunnel

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ABSTRACT
A double lane access tunnel of about 1.5 km length is proposed for access to an upcoming major hydro-electric project in Ramban & Udhampur districts of Jammu & Kashmir. The tunnel is accessible through inlet only (East portal) and is located at left bank of the Mandiyal Nalla.Severe water ingress was encountered during heading excavation at RD 855.00m. The quantum of ingress of water was so huge that the tunnel rapidly got flooded up to RD 221.00. The project area lies in Sirban Limestone represented mainly by dolomitic limestone with bands of dark grey to black slates.In spite of large dewatering, the ingress of water could not be controlled to the desired extent, thereby acutely signifying the gravity of water. After grouting with cement, it was found that the grouting works are ineffective in arresting the heavy ingress of water inside the tunnel.Further, trial of PU grouting was done with the deployment of expert executing agency. This trial succeeded by 85% stoppage of water ingress.

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I. INTRODUCTION

A double lane access tunnel of about 1.5 km length is proposed for access to an upcoming major hydro-electric project in Ramban & Udhampur districts of Jammu & Kashmir. It is a run-off- the river scheme across the river Chenab with approximately installed capacity more than 1500 MW. It envisages construction of approx. 200m high Roller Compacted concrete (RCC) dam, an upstream short water conductor system, an underground powerhouse in the left bank downstream of dam axis and a tail race system.

Since the hydro project lies in the narrow gorge of Chenab, it is difficult to plan/ construct surface access to various components of the project. Therefore, an access through 1.5km long all-weather tunnel has been proposed for the project. This tunnel is being constructed ahead of start of works of hydro project as an enabling task and named as double lane access tunnel to HEP. The tunnel has three components: Inlet Portal, Tunnel & Outlet Portal.

The Inlet portal is located at external access road (EAR) to the left bank of Mandiyal Nalla which is made accessible through a bank road from right bank to the left bank of the nalla.

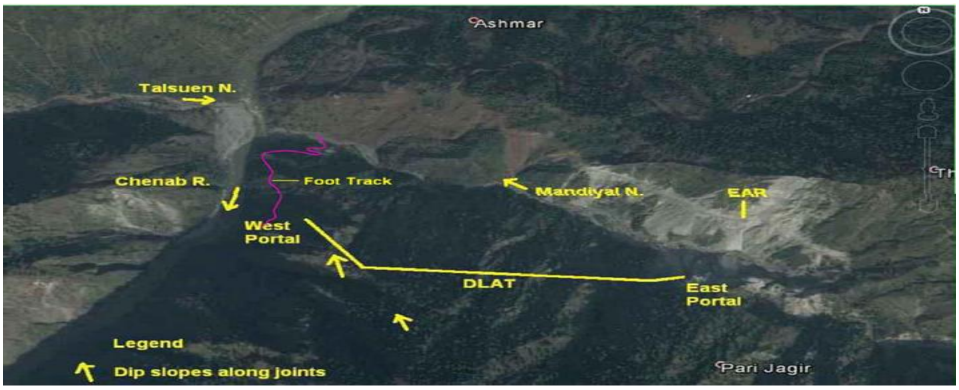

Figure 1: Tunnel Layout

The outlet of tunnel has a dead end to serve the purpose of ventilation for various accesses connected to this through a spiral tunnel.The tunnel has been designed as modified horseshoe shaped with finished size 9.35mx8.0m. The tunnel was being excavated in heading and benching.

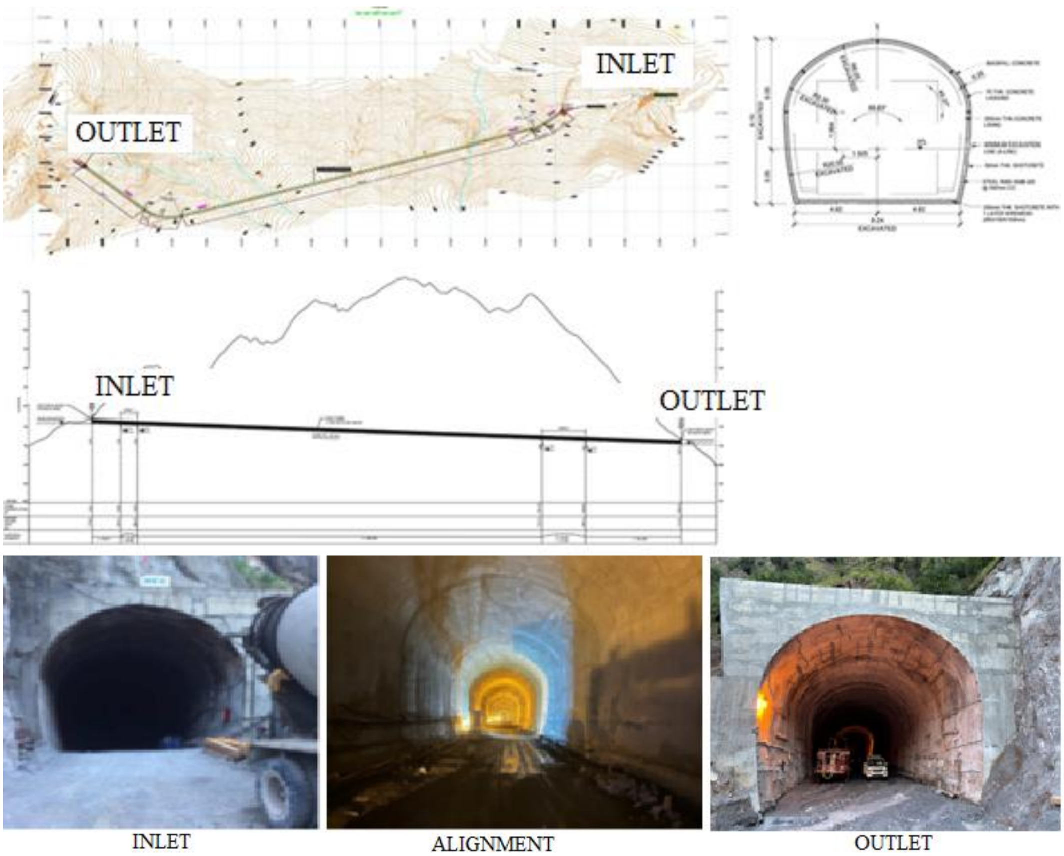

Figure 2: Tunnel Layout and Components

II. THE PROBLEM

During excavation of the tunnel, first incidence of heavy water ingress with intensity 3300 - 5800 LPM was encountered from unexpected sources at RD 427.00m. All the tunneling works except dewatering had to be stopped. Heading excavation was resumed along with round the clock dewatering with 135 HP submersible pumps.

Againsevere water ingress was encountered during heading excavation at RD 855.00m. The quantum of ingress of water was so huge that the tunnel rapidly got flooded up to RD 221.00. Since the exact location, geometry and ground water pressure head with which the water is inflowing could not be seen at this stage.The discharge could be assessed and was considered to be in the range of 21000 - 22000 LPM. The water ingress was once again encountered at RD 928.5m, leading to flooding of tunnel up to RD. 840m, estimating the discharge being 25000 – 26000 LPM.

Since, the tunnel was aligned in negative slope i.e. inlet level was higher than the outlet, the water could not be drained out by gravity. Therefore, the heading work halted till the dewatering could be done.

Figure 3: Tunnel flooding and water ingress

III. GEOLOGY

In the project area, the river Chenab flows in a general NNE-SSW direction through a deep gorge. Two major tributaries with well-defined valleys, viz. Mandiyal nala and the Talsuen nala, join the Chenab River on left and right bank, respectively, immediately upstream of the tunnel alignment area. These two linear tributaries are strikingly opposite to each other and owe their origin to the major regional fault that runs along them in Himalayan Geology. The general orientation of these nalas is NW-SE. The mountains flanking the Chenab rise to heights over 900m, attaining elevations of 1400m and more. The river Chenab lies at an elevation of about 600m at Mandiyal confluence and at El ~550m below the tunnel west portal site.

Figure 4: Geology in vicinity

The valley slopes are fairly stable, and any major landslide is not seen in the area. As an exception, however, the destabilization of slopes due to excavation of the EAR has apparently led to development of some active slide zones.A hot spring is reported on the right bank of the Chenab close to the downstream edge of the wide Talsuen flood plains opposite Mandiyal confluence.

The project area lies in Sirban Limestone represented mainly by dolomitic limestone with bands of dark grey to black slates. The sedimentary sequence of interbedded sandstone and shale belonging to Tertiary Murree Group lies immediately upstream of the tunnel alignment at a minimum distance of 425m. The contact between the Sirban Limestone and Murree Group is represented by a major regional fault. The rocks are profusely exposed on the valley faces and wherever covered the overburden of slope wash is believed to be thin.

The traversed area around the tunnel alignment is found in a dry state except for the perennial gulley and adjoining waterfall towards the west end. The estimated waterfall discharge of about 6000 LPM is considered substantial and is indicative of the presence of aquifers in the rock mass above the west portal, which are seasonal. In consideration of the surface water scenario, the subsurface water in the proposed tunnel is expected to be moderate with the exception of the west portal area where seepage conditions may assume greater proportions.

It is, therefore, estimated before start of excavation that the tunnel, in general, may be in fairly dry to moist condition with occasional dripping or seeping zones related to jointed, fractured or sheared strata. The inflow is expected to be less than 125 LPM. Free flowing zones with discharge of >125 LPM are not expected, particularly towards the west portal where the outward gradient of the tunnel would help drain the seepage water under gravity. Possible presence of free-flowing conditions along fracture zones or shear zones is not ruled out.

Rock Mass Classification

For geotechnical assessment of the tunnel, the Rock Mass Quality ‘Q’ and Rock Mass Rating (RMR) have been used as the rock mass classification systems. The data on engineering properties of joints and Joint Volume ‘Jv’, collected during engineering geological mapping and associated discontinuity survey, have been used for the computation of ‘Q’ and “RMR” values. On the basis of Q and RMR values, the rock mass has been divided into five Rock Classes viz. Rock Class I - Rock Class V, as given in following table:

ROCK CLASS AS PER GEOLOGICAL MAPPING VS ACTUAL ENCOUNTERED

Sl. No.	RockClass	%age assessed as per Geological	%age assessed as per Geological
1	I: VeryGood	0	0
2	II:Good	15	7
3	III:Fair	65	37
4	IV:Poor	10	22
5	V: VeryPoor	10	34

IV. POSSIBLE REASONS

Earlier it was assumed that it might be a perched aquifer which will dry with time, but it is almost four years of mining (2018 – 2022) and water ingress inside tunnel is continued, affecting construction activities inside the tunnel. Such a long-time water ingress indicates that these are permanent aquifers having a constant recharge of water from surface. We can divide the water bearing pockets in the rock mass called aquifers into following types: Pore aquifer rock group in the valley ground; Fissure and Karst Cave aquifer rock group in the Carbonatite; and Fissure aquifer rock group in the bed rock. Among them, the Fissure and Karst - Pore Aquifer rock group in the Carbonatite is mainly distributed in the Sirban Limestone and its lithology includes limestone, dolomite, marble, marlstone and so on, may be the root cause of the inrush water problem.

The puncturing of the perched aquifer during the excavation cannot be ruled out in this section of the tunnel.Rock outcrops are outcropped area of carbonaceous rock mass with many complex folds has significant impact on water in rush because their core and flanks easily store water and form water channels.

A survey was carried out to assess the condition of surface water bodies in the vicinity of the project or at the top of hill. Teams visited various locations to assess the possible depletion of water sources and interacted with the residents in the proximity. No reports were received of surface water bodies and depletion of any source of water.

V. HANDLING OF PROBLEM

During first encounter of ingress at RD 427m,heading could be continued with the increased pumping system. However, next water ingress at RD. 855 was such a severe that existing arrangements of dewatering were not appropriate. This situation worsened due to reverse gradient and the tunnel got flooded up to RD 221m towards portal side resulting submergence of the existing pumping system near the face. Therefore, rest of pumps were shifted to the safer place.Further, a trench was excavated towards inlet portal side to tackle the untoward situation of water coming out of the portal and protection from any unprecedented situation of bank erosion.

The dewatering capacity was increased from35 HP pump to 275 HP capacity and then 535 HP. Despiteof large dewatering, the ingress of water could not be controlled to the desired extent, thereby acutely signifying the gravity of water.

However, to mitigate the impact of the impediment mentioned and considering inaccessibility of Outlet, it was proposed to construct a drift/ drainage gallery of approximate size of 2.5m x 2.5m simultaneously from outlet end. Later this drift at Outlet end was developed as Outlet portal of the tunnel.

It was anticipated that, the drift can attract any water body available in the vicinity and in turn would help dewatering by gravity on meeting with the heading excavation. The drifting was stopped after 150m excavation due to encounter of water ingress.

The discharge of water in the tunnel was assessedby adoptingfollowing methods:

A. Flooding time of tunnel and extent of flooding
B. Filling of water container
C. V-notch method

During initial assessment of water ingress quantity/ intensity, the volume of tunnel flooded in the reported time was worked out and considered as the discharge of ingress.When flood dewatered and execution started, the intensity was tried to assess by filling empty large drum with noting the time of filling. Although it is a crude method of estimation but did helped to assess the intensity.

Further, a V-notch was constructed to estimate the intensity of water ingress. The V-notch was constructed based on the guidelines of IS;14750. A channel was constructed to flow the water up to the location of V-notch. The discharge was calculated using formula given below: -

Figure 5: V Notch

$$Q = 0.0138H^{(\frac{5}{2})}$$

Where, Q = Discharge in LPS and H = head in cm

VI. TREATMENTS EXECUTED

Initially it was proposed to grout the sides and crown with cement along with admixtures to control ingress of water. The grout was proposed in the adjacent dry areas from a distance of about 10 to 15m, and then proceed towards minor trickling/ leaking zones, before grouting severe inflow zones. Perforated drainage pipes of requisite length but not less than 6m to 10m, depending upon inflow conditions, be installed before grouting the leaking zones, to concentrate the inflow through these drainage holes.After grouting with cement, it was asessed that the grouting works are ineffective in arresting the heavy ingress of water. Further, it was proposed to grout the tunnel at ingress location with PU material.

At first phase, a trial of PU grouting was done with the deployment of expert executing agency. The trial of PU grouting was conducted on from RD 953 M to RD 957 M in Rock Class V. Three chemical type PU materials were used in groutingi.e. MasterROC MP 355 Part A, MasterROC MP 355 Part Band MasterROC MP 355 Accelerator 10 in the ratio of 25 Kg: 30 Kg: 250 ml respectively.Drill holes of 64mm dia & 4 m depth were prepared and grouting was done using 48mm dia mechanical packer of 1 m length in 3.5m long 51mm dia GI pipe. The trial was conducted in five holes in which it was observed that in the first hole success rate of PU grout was 85% due to improper packing and fixing of mechanical packer in hole whereas success rate of rest 4 holes was 100%. It was concluded that the PU grouting trial was successful to stop the ingress of water.

VII. SIMILAR LITERATURE REVIEW[4]

Pir Panjal (T-80) is the second longest transportation tunnel in India and third in Asia covers the construction of 11.2km long tunnel; this is the third longest railway tunnel in India, next only to Pir Panjal. This is the part of Udhampur-Srinagar-Baramulla Broad gauge railway line, which is one of the mega projects undertaken by Indian Railways to establish a dependable transportation in the state of Jammu and Kashmir.

During tunneling from the Adit towards the north portal, heavy seepage, from the starting end of the tunnel, i.e. about 2750.00m south, was faced. The seepage varies from 25.00 liters per second to 280.00 liter per second (1500-16800 LPM), leading to face collapse and cavity formation and creating hurdles in the application of shotcrete and other primary supports.

Heavy water ingress inside tunnel was due presence of open joints, heavy snowfall over the project, presence of perennial stream across the tunnel and formation of aquifer around the tunnel and regular recharge of aquifer through the stream.Situation tackled by stopping the heading and starting the benching and face work was discontinued for 3 months to drain the water. Due to this water discharge reduced and measured around 110L/sec (6600 LPM).

VIII. DISCUSSION AND CONCLUSION

The water ingress in calcareous rocks may lead to disaster, if not treated in time. Sometimes, they can sustain as in the case discussed above. The conclusion of this case study can be encapsulated as below: -

i. The dewatering process from the filled tunnel should be started immediately without wasting time with high-capacity pumps; otherwise, the chemical weathering of the calcareous/ carbonatite rock mass with water could start which may lead the caving effect in the excavated tunnel portion.
ii. Generally, the amount of water flowing from the tunnel decreases as construction progresses. This is due to the gradual exhaustion of water at source. Therefore, time is also one of the factors which may be observed because if the size/dimension of the punctured aquifer is small then the inflow of the water would decrease considerably with the passage of time. But in present scenario, the water ingress has been continued since 2018 to till date.
iii. Cement grouting with the combination of admixtures was tried but could not be successful.
iv. The application of PU grouting was successful to an extent of 85%.
v. If the intensity of the water in flow continues and cannot be controlled by all mentioned methods, then the shifting of the layout of the tunnel alignment might be considered.
vi. Since, this tunnel is connected to an upcoming major hydro-electric project, therefore, shifting can be need a mindful attempt by keeping in view the overall layout of the project.

REFERENCES

[1]. Geological Mapping report of the Project
[2]. Various site visit reports during the project execution (project is still under execution)
[3]. DPR of the upcoming hydro-electric project, connected to the tunnel project.
[4]. Conventional Tunnelling Challenges In The Himalayas: A Case Study Published in CE&CR by Mr. Rakesh Khali and Mr. Sharanappa Yalal