

Tunnel Excavation and Support in Exceptionally Poor Rock Mass (Shear Zone) Condition in Lesser Himalaya, Nepal: Case Study of Upper Kabeli Hydropower Project (28.1 Mw), Taplejung Nepal

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Abstract: Thin to thick (few cm to several m) shear bands and shear zone are commonly encountered during tunnel excavation in lesser Himalaya. 25.5 m thick shear zone is encountered (Ch: 4+075.75-4+032.25) during excavation of Headrace Tunnel from outlet of UKHPP. This shear zone (weak section) consists of light greenish gray silty clay with some weathered phyllite fragments. Groundwater conditions during excavation is dry and the Q-value is exceptionally low (<0.01). The attitude of shear zone is 220-240/40-50 (DD/DA) and makes oblique striking with tunnel direction (008) and foliation (70-100/20-30). Sequential heading and benching excavation and immediate support installation works are adopted for the safe excavation of the weak section and 50 more days were spent to excavate the 25.5 m stretches. Non-core recovery probe drilling is conducted for the direct investigation of the onwards rock mass condition.

Keywords: Excavation, Tunnel, Heading and benching, Shear zone.

fragments of deformed quartz veins were also observed within phyllites. The rock mass downstream to weak section was highly fractured and consists of three to three joint sets (3+R). The joint sets are not very distinct but have smooth planar to undulating surfaces. The joints are tight to open (~4 mm) and are infilled with silt and clay materials. The persistence of joints ranges from low to medium (1-10), with spacing between 0.05-0.5m. Groundwater conditions during excavation and face mapping were dry to damp and Q-value is exceptionally low (<0.01). Attitude of the shear zone is 220-240/40-50 and have oblique relation with tunnel direction (008) and foliation (70-100/20-30) too. After excavation up to chainage 4+044.85, weak section (sheared zone) gradually decreased and moved towards crown portion. Summary of the rock mass classification of HRT-outlet section is shown in Table 1.

Introduction

4896 m long Headrace Tunnel (HRT) (4.3 m*4.45 m, B*H) of Upper Kabeli Hydropower Project (UKHPP), 28.1 mw is located in the lesser Himalaya zone of Nepal at Taplejung District. The major rock types of the project area are Metasandstone, Phyllite and Schist. Rock mass condition encountered in between chainage, 4+075.75-4+032.25 m (25 m) is exceptionally weak at outlet section of HRT. This weak section (shear zone) comprises of light to medium dark gray silty clay with some rock fragments. Occurrence of sheared bands, sheared zones, weak zones and groundwater are commonly encountered geological feature during underground excavations within the Nepal Himalayan region (Sunuwar, 2016). These weak zones are developed develop due to faults, folds, rock mass shearing, chemical alteration, stress anisotropy, and other factors. The orientation of foliation changes after the shear zone. Generally East orientated (70-100) foliation is change towards NNE to NE (10-50) direction with almost same dip amount.

Geological Condition

Weak section (4+057.75 to 4+032.25)

The excavated rock mass mostly consists of sheared zone comprising with light greenish gray silty clay (90-95 %) with light greenish gray, highly weathered, thinly foliated, very low strength phyllite at invert level (5-10 %). Some

Excavation and Support Installation

To prevent the cavity formation/overbreak and strengthen tunnel stability, sequential heading-benching and immediate support installation methods are adopted for the safe excavation of the weak zone. The installed rock support at very weak zone includes steel rib sets (ISMB/ISHB 150*75, 150*150), invert strut, anchor bar, steel fiber shotcrete, shotcrete, spilling/fore polling rod, rock bolts etc.

Tunnel Squeezing

In Nepal Himalaya, rock squeezing is common problem while tunneling through the shear zone dominant in clayey material (Sunuwar, 2006). In medium to high stress conditions, weak rock mass containing shear zone is squeezed during and after support installation. The vertical cover at this section is 300-315 m. As we excavated this weak section by heading and benching method. Initially, upper half of the tunnel is and then crown portion of rib was fixed immediately after survey. But during the time of fixing of rib vertical leg, the crown plate/flange were squeezed by 10-15 cm each from each side. In short, 5 m stretches weak section is squeezed maximum up to 30-40 cm. Installation of inverted strut and its bracing with vertical anchor help to control and minimize the tunnel squeezing condition. Measurement and monitoring of deformation is continued at the weak section to know

squeezing condition and ground response to the applied support system.

Table 1, Summary of Rock Mass Class Classification, Outlet, UKHPP.

HRT-Outlet-U/S					
Chainage (m)		Length (m)	Q-Value	Rock Support class	Initial rock support
From	To				
4+175.30	4+161.92	13.38	0.04-0.2	IV	R/B, S/C,
4+161.92	4+153.69	8.23	0.01-0.04	V	Rib, R/B, S/C Spilling
4+153.69	4+106.30	47.39	0.04-0.2	IV	R/B, S/C,
4+106.30	4+086.51	19.79	0.7-0.7	III	R/B, S/C,
4+086.51	4+057.75	28.76	0.01-0.04	V	Rib, R/B, S/C Spilling
4+057.75	4+041.55	16.2	<0.01	VI	Rib, R/B, S/C Spilling
4+041.55	4+032.25	9.3	<0.01	VI	Rib, R/B, S/C Spilling
4+032.25	4+018.85	13.4	0.01-0.04	V	Rib, R/B, S/C Spilling
4+018.85	3+980.01	38.84	0.04-0.2	IV	R/B, S/C,

Probe Drilling

Probe hole drilling was executed to find out the onward rock mass condition. This method involves advancing the borehole ahead of the excavation face to gather critical data about rock mass condition, water present etc. 6 nos of probe holes (each 14.2 m long) are drilled at different spots of face (chainage 4+047.75). Probe drilling suggested the improving rock mass condition onward 10 m from the face chainage. Though the probe drilling is non-core recovery type, the condition of rock strata is analyzed by the drilling time and the dust material recovered during drilling.

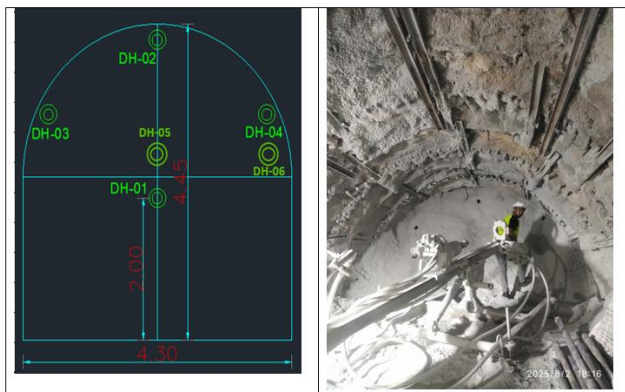


Figure 1, Probe hole location drilling at ch:4+047.75.

Conclusion

Adverse geological condition is encountered at HRT- Outlet US (Upper Kabeli Hydropower Project), on July 04, 2025, between chainages 4+057.75 and 4+032.75. Within 50 days, this 25.5 m thick shear zone is excavated very slowly and safely without any major over-break within 50 days. All the rock support measures are applied as per site engineers' instruction as provided by expert suggestion. This section is excavated by heading and benching methods

with immediate support installation. Various rock supports such as steel rib sets (ISMB 150*75, 150*150), invert strut, anchor bar, steel fiber shotcrete, plain shotcrete, spilling rod, rock bolts etc.

Recommendation

Following recommendations could be drawn from excavation and support installation of very weak geological condition.

- Analyzing the condition of the excavated rock mass and making a pre-judgment of the upcoming rock mass condition before the excavation of the tunnel face are critical in underground excavation. This analysis aids in selecting the appropriate excavation procedures, support systems, and installation methods. Implementing these practices will enhance the safety and efficiency of the excavation process.
- Continuous observation and monitoring of weak zone section and ground response to the applied support system are crucial to identify any potential failures and implement necessary support measures.

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