Journal of Engineering Geology *Volume XLIV, Nos. 1 & 2*
A bi-annual Journal of ISEG *June & December 2019*

Excavation of silt flushing tunnel (SFT) in difficult geological conditions-A case study

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Abstract

TapovanVishnugad Hydro Power Project (TVHPP) ,520 MW is located in the Central Crystalline rock mass.The project is run- off river scheme and under construction in the river Dhauligangain theChamoli district of Uttarakhand. Silt Flushing Tunnel (SFT) of 3x3.5m dia.D-shape is under construction in metabasic rock and alluvial deposit. Previously total length of SFT was 2362m, due to excavation in extremely poor rock mass condition from old outfall portal andto minimize the time of excavation length of SFTwas reducedto 1465m.

The rock mass exposed in old out fall area is comprises of sheared /crushed, highly fractured & jointed quartzite .Clay filled joints are common in this area (around the old SFT out fall portal).The Dhaknala has formed a huge alluvial fan depots comprising angular to sub-angular boulders of varying size of banded streak by augengneiss,amphibolite and quartzite embedded in gritty matrix .The width of fan varies from 50 to 200 m .In-situ rock mass is absent in the area located between left bank of Dhaknala and SFT out fall (old)and huge depotsmostly glacial debris /moranies/glacial outwash (over burden material) is observed .The new alignment of SFT with lesser length than the previous alignment will pass below the alluvial fan deposit and rock mass near the Dhaknala.Which will also excavated in difficult geological conditions.

Out of 1465m length 880m excavation of SFT iscompleted, slope treatment for the construction of new out fall portal is completed, and excavation is started from new out fall portal.A cavity was formed at RD 59.5m, just below the nala during excavation and it was continued up to the RD 65m.The rock cover above the cavity zone varies from 46-52m.Treatment of cavity was successfully done;in this paper,challenges in progressive excavation of tunnel, excavation methods used, rock support system adopted and rock mass encountered with the emphasis on treatment of the cavity zone are described in detail.

1. Introduction:

TapovanVishnugad H.E. Project (4 X 130 MW), is a run of the river scheme, harnessing the potential of Dhauliganga river, and is under construction in Chamoli district of Uttrakhand. It involves construction of barrage, comprising of four bays of 14m each,intake structure and desilting chambers. This run of the river project utilizes the discharge of river Dhauliganga and envisages the utilization of 532m gross head through 12.087 Km long Head Race Tunnel (HRT) 5.64m dia.Major portion of the HRT i.e. 8616m is being constructed by a double shield Tunnel Boring Machine (TBM) from one end. The powerhouse complex comprises of underground power house(158.5x22x48.72m) ,transformer hall (147.75x18x27.65m),surge shaft of 13.5 m dia and 147.2 m height, with two inclined pressure shafts of 4.6 m dia& 522.91m length, which bifurcate into two penstocks each. Tail race tunnels (439m length & 7m dia.) and outlet structure has been constructed to discharge the flow into the Alaknanda river.

In order to flush out silt from de-silting arrangement a 1465m long tunnel is under construction.Silt flushing tunnel has four limbs of different length. During design stage various alternatives for SFT was explored. Due to difficulties faced the old SFT outfall after construction of 96m was abandoned. A new out fall portal is developed before the DhakNala and 22m of tunneling has been completed in the overburden. Changing of old outfall portal to new outfall portal of SFT ismainly for time saving for construction. Main geological problems are encountered during excavation of SFT are poor rock mass conditions at SFT limbs,formation of cavity at RD 59.5m,extremely poor rock mass encountered from Old SFT out fall area, at SFT D/S right side (SPL to crown) water ingress was observed.Compacted alluvial material of various size are observed from new location of outfall portal.Layout of old and new SFT alignment is shown in fig.-1.Excavation of SFT u/s and d/s was carried from junction point of SFT &adit to SFT.In the u/s direction after 121m four number of limbs were constructed mostely in poor rock mass condition.The same was supported with steel rib's.In addition to design support additional support was installed during excavation.At the d/s of junction mainly fair rock mass condition was observed with some zones of poor,very poor and extremely poor rock mass and cavity at RD 59.5m.From the old outfall portal excavation was done in exrtremenly poor rock mas conditions.The same was supported by steel ribs.In the new out fall portal mostly compacted alluvia material is observed and being supporeted with steel ribs.

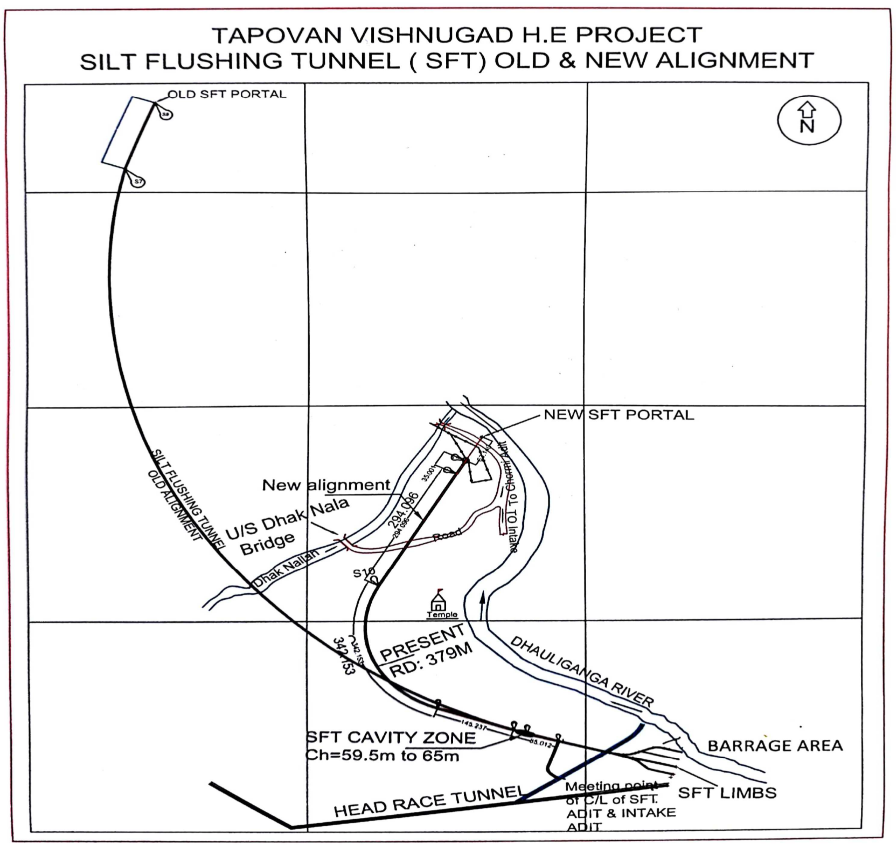

Figure1 Silt Flushing Tunnel Alignment

2. Geology of Project Area:

The project area forming a part of Dhauliganga and Alaknanda valley exposes rocks classed as Central Himalayan Crystalline by Heim &Gansser (1939) and are composed mainly of medium to high grademetamorphics. The crystalline rocks of the Dhauliganga valley derived from pelitic, semipelitic&psammitic sediments which occasionally are interlayered withmetabasics and to a lesser extent in DhakJharkula area calcareous rocks are also recognized. Towards the south, the crystallines are thrusted over the lesser Himalayan sediments of Garhwal Group of rocks by MCT . Main Central Thrust (MCT) passes through village Helong located 3 km. down stream of the power house site area.

The grade of metamorphism increases northward from Helong to Joshimath and from Tapovan to Joshimath, ranging from biotite grade near Karchhi and Animath village to Garnet grade near Tapovan and Helong to staurolite grade near Bargaon, Parsari and JogiDhara area. These rocks gradually pass into the Kyanite zone. In a broader sense we can categorize the rocks of this area into two formations namely Tapovan andJoshimath formations shown in Table -1. In between Tapovan (Helong) and Joshimath formation there is no shear plane or plane of discordance nor there is any topographical break. The rocks here exhibit a progressive northward increase in grade of metamorphism and a well-marked continuity of different tectonic elements.

Table 1
Litho-Tectonic Setup of the Tapovan - Vishnugad H-E Project.

LITHO-UNIT	LITHOLOGY	GRADE OF FACIES	METAMORPHISM	TYPE LOCALITY
Joshimath Formation	Coarse Garnet Mica Gneisses, Garnet-Kyanite Gneisses	Amphibolite Facies	Kyanite Zone	Joshimath, Bargaon, Auli, Sunil, Parsari, Mirag
Tapovan Formation (Helong Formation)	Mica Schist, Amphibolite, Augen Gneisses, Garnet Mica Schist. Fr. Gr. Banded Gneisses, Quartzite	Amphibolite Facies Green Schist Facies	Garnet Zone	Between Helong&Joshimath in Alaknanda Valley & Bargaon to Tapovan in Dhauli Ganga Valley
Garhwal Group	Limestone, shale, Quartzite & marble	Green Schist Facies	Chlorite Zone	South of Helong in Alaknanda valley

The general strike of foliation is NW-SE and dips at 30º to 45º towards NE. The gneisses of Joshimath area dips mainly in the NE direction with considerable local variations.

3. Geology along SFT alignment:

Detailed geological mapping of SFT was carried out on 1:2000 scale, the main geological details are as follows:

(i) Geology between Intake structures to DhakNala:

At left bank of intake structure the rock mass consisting of very hard, compact, moderately jointed gneiss are exposed. The slope is almost vertical, the foliation dips at 15-20 ^{0} in N320 ^{0} direction .Five joint sets are recorded in this area.
Near intake adit rock mass is hard, compact, jointed, having foliation joint 010/N245 ^{0} with other four sets of joints are present.

Near the site office of NTPC the rock mass is augen gneiss /amphibolite .The foliation is dipping in 030-35 ^{0} /N090 ^{0} (upstream dip) .Two other set of joints are recorded in this area.

Towards of DhakNala at road level contact of overburden and rock is observed.The rocks exposed are gneiss with quartz veins.

(ii) DhakNala Section:

On the right bank of DhakNala in upper reaches in-situ rock exposes .The DhakNala has formed a huge alluvial fan deposit comprising angular to sub angular boulders of varying size (from 25cm -1.6 m dia.) of bandes streaky augen gneiss and quartzite embedded in gritty matrix.The width of fan varies from 50 to200m.

(iii) Geology between left bank of DhakNala and SFT out fall (old out fall) area:

In the area located between left bank of DhakNala and old SFT out fall in –situ rock is absent and huge deposit mostly glacial debris /moraines /glacial outwash (overburden material) is observed.The overburden material comprises rock blocks varying in size from pebble to large boulder embedded in silt,clay, sand and gritty matrix. The matrix is rich in micaceous content and it is non-cohesive in nature.

Two no's of drill hole were drilled along the alignment of SFT near DhakNala area. Geophysical investigation were also carried out below the fan in the new alignment,details of same are nor described here.

4. Cavity Treatments:

During excavation of SFT d/s at RD 59.5m loose rock mass was observed from the crown portion , rock class was very poor. After few days, water ingress was also noticed with the rock mass. Shear zone material encountered is shown in the photograph 1.

Photograph 1 Shear Zone Material from Cavity

Probe holes of various length was drilled for understanding of rock mass material ahead of the tunnel face.During stabilization process heavy flow of slush was observed .Cement grouting with other support measures were taken for advancement .Some cracks were developed at the surface. Cracks at the surface are shown in the photograph 2.

Photograph 2 Surface Cracks above the Cavity Zone

During advancement it was decided to use chemical grouting for controlling water ingress. Face was plugged by erecting bulk heads for allowing the face to stabilize.After few days face stabilization was again attempted but ,slush flow continued ,the face was plugged again. To control the situation chemical for grouting was changed and 5 m advancement was achieved.Tretement procedure of cavity is shown in the photograph 3. Based on results and dealing with this cavity zone following sequence of activites was adopted as per the site condition:

1. Drilling and forepoling.
2. Drainage holes in crown and side walls.
3. Shotcreting of the face.
4. Drainage holes at face over shotcrete.
5. Cement grouting at crown and face.
6. Chemical grouting at face.

7. Plugging of face for stabilization.
8. Removal of bulkhead and excavation.
9. Shotcreating of face.
10. Removal of benching bulkhead and excavation.
11. Shotcreating of face and rib erection.

Photograph 3 Treatment of Cavity Zone

Steel ribs were stenghned by channels.During treatment procedure from RD 59.5m to 65m,face collapse was happen four times. The material observed from these zones was sheared in nature with large rock pieces, small fragment of rocks .The main cavity zone was from RD 59.5-65m after that extremely poor rock mass was observed up to the RD 81.5m.The above mentioned sequence was followed based on rock mass material .This is successfuly resulted trackling of shear zone and extremely poor rock mass of almost 22m.

5. Conclusion:

It is always misunderstood that smaller size tunnels can be excavated easily. But if shear zone encounters with different type of materialsthen situation is different. After trackling the cavity zone from RD 59.5-65m ,extremely poor rock mass conditions further slowdown the progress. However, an experienced crew and proper methodology based on site observation can overcome the tunneling challenges.

Acknowledgement:

Authors are thankful to the construction team for contribution andnegotiating the difficulties during the work. The views reflected in this paper are purely of authors.

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