Accelerated Approach in Construction of HRT of Maneri Bhali H.E. Project (Stage II) Using Swellex Rockbolts - A Case Study

P.K.Gajbhiye* & N.R.Bhattacharjee**

Abstract

Tunnels and underground excavations are part of most of the hydroelectric projects. Apart from various geotechnical challenges, completion of the project within scheduled time is a big challenge. Therefore, modern tunneling techniques have drawn the attention of geoscientists for speedy and safe construction to complete the project within scheduled time. Rock bolting is an important technique in tunneling, applied for providing immediate support to surrounding rock mass. The paper highlights the 'accelerated approach' applied in excavation of Head Race Tunnel (HRT) of Maneri Bhali H.E. Project (Stage II), where Swellex rock bolts were used instead of conventional rock bolts. This has helped in reducing the cycle time considerably resulting in increase in average monthly progress of HRT excavation. Swellex is a friction-type rock bolt, which adjusts itself in the irregularities of the hole and permits very small movements in rock without adverse effects. Installation of this rock bolt is very fast (2 min/rock bolt), simple and safe as compared to the conventional rock. These special qualities of the Swellex rock bolts hold the key for preference over conventional rock bolts whose installation is time consuming and laborious. A comparative study and experience of tunneling brought out the fact that, before implementation of the 'accelerated approach' it took almost 11 years to construct the 9.16 km long portion of HRT whereas, remaining 7 km of HRT excavation was completed in only 41 months.

Introduction

Maneri Bhali Hydroelectric Project is a run-off the river scheme on River Bhagirathi. It involves construction of 81 m long barrage, a 16 km long and 6 m diameter horse-shoe shaped Head Race Tunnel (HRT), 4 penstocks, 174 m high & 14 m diameter surge shaft and a surface powerhouse to generate 304 MW (4 X 76 MW) of electricity (Fig. 1). The project was formulated after many changes in the initial plan and construction activities started by the end of nineteen seventies. After completing nearly 60% of the work, the activities came to standstill in 1991. With the formation of Uttaranchal State, renewed interest was shown on the project and impetus was given to complete the project within 39 months and the construction work resumed on 18th July 2002. Considering the time constraints and the geological complexities of the region, it was a challenging task to complete the project within stipulated time frame. To achieve the target, many changes regarding time management were incorporated to accelerate the construction. Author discuss the use of Swellex rock bolts as one of the prime tools to reduce the cycle time of excavation is discussed.

Geology of the project area

The rocks in the project area belong to Jaunsar and Garhwal Groups. These two are separated by southwest dipping structural dislocation i.e. *Srinagar thrust*, which is northwest extension of North Almora Thrust. The stratigraphic succession of the project area is given in Table-1.

*Geologist, Geological Survey of India, Dehradun, E mail-pkgajbhiye@yahoo.com
**Geologist, Geological Survey of India, Lucknow, E mail-nihar_bhatt @yahoo.com

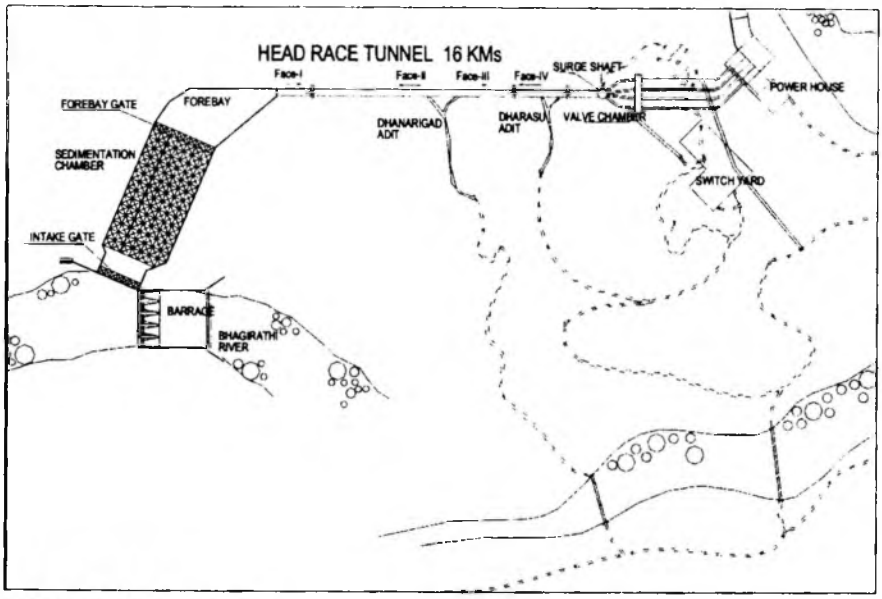


Fig. 1: Layout of the project

Table 1. Stratigraphic succession in the project area

GARHWALGROUP	Nagni Thank Formation	a) Upper meta-volcanics, amygdoloidal andesites etc.
		b) Gamri quartzite with Basic intrusives (epidiorites)
		Lower meta-volcanics with slate and Quartzite bands
	Shyalana Formation	Limestone and dolomite with minor quartzite.
	Uttarkashi Formation	Grey, green and purple slates banded
----------SRINAGAR THRUST (NORTH ALMORA THRUST) ----------		
JAUNSAR GROUP	Tehri Formation	Phyllites and greywacks with occasional calcareous lenses and basic intrusives (epidiorites.)

The barrage, intake and sedimentation chamber are located on slates while, the powerhouse is on phyllites and meta-greywackes of Tehri Formation of Jaunsar Group. The HRT passes through all the rock types of Garhwal Group and Tehri Formation from intake to surge shaft (Fig-2).

Head Race Tunnel

Topographical and geological features

The 16 km long HRT is located on the left bank of River Bhagirathi. It crosses two deeply incised major drainages and southwesterly dipping tectonic feature *Srinagar Thrust*. Total thickness of this thrust zone along the alignment was found to be ±210 m. The vertical cover over HRT ranges from 21 m to 976 m along the entire length. To facilitate a speedy progress, excavation of the tunnel was planned from five faces. The tunnel passes through bedrock comprising limestone with slate inter-bands, meta-basic with schistose inter-bands, quartzite, meta-greywacke and phyllite. The tunnel alignment is mostly perpendicular to foliation/bedding of the rock strata.

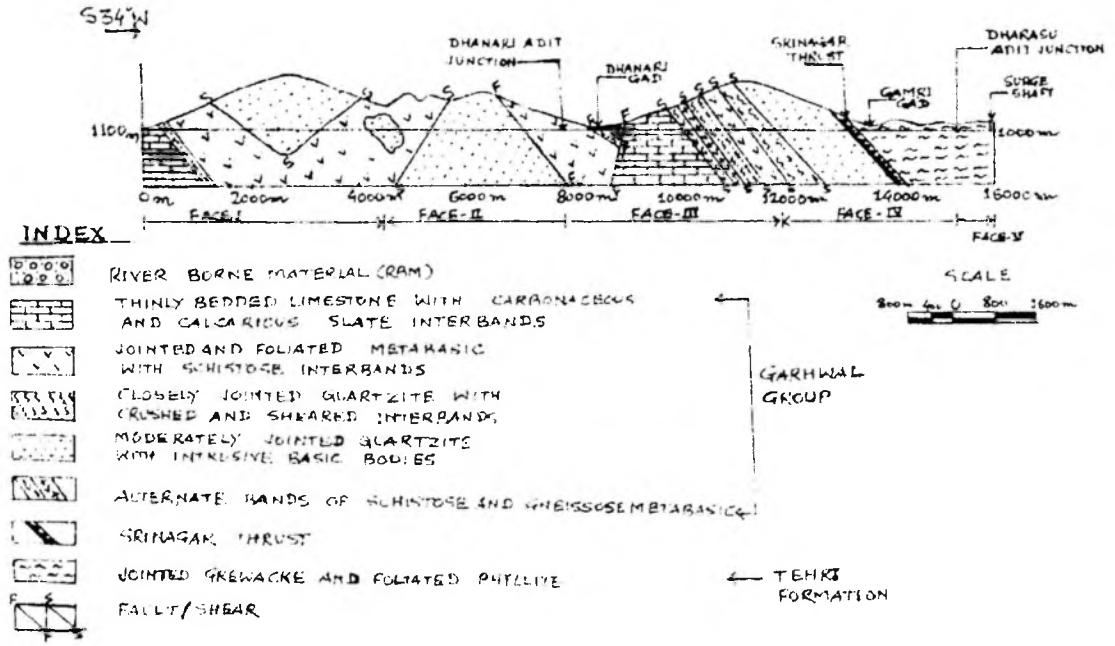


Fig. 2: Geological Section along HRT

Excavation Methodology

Prior to suspension of work in 1991, almost 9.16 km of excavation of HRT was completed and it was driven through rocks comprising mainly limestone, metabasic, greywacke, phyllite and *Srinagar Thrust* zone. The excavation methodology adopted includes conventional drill & blast, mucking by rail mounted wagons, rock support mainly by steel ribs in most of the sections and mechanical rock bolts in a few sections. It took almost 11 years to excavate 9.16 km length of HRT from different ends.

In the backdrop of earlier conventional and time-taking methodology, it was the need of the hour to adopt innovative techniques to speed-up the work for remaining length of HRT, so as to complete the project within stipulated time frame of 39 months. Therefore, after resuming work in the year 2002, NATM technology was adopted for remaining ± 7 km of HRT excavation. In this 7 km reach, the tunnel passes through quartzite (almost 80%) and meta-basics of 'Fair to Good' (Class III to II) and 'Poor' (Class IV) grade. The excavation methodology adopted included mechanised drill & blast by rocket boomer, semi-mechanised mucking and rock support mainly by Swellex rock bolts with steel reinforced shotcrete (Sfr) and steel ribs exclusively for critical sections. The Swellex rock bolts were installed just after the excavation to provide instant support. The excavation by NATM and rock-strengthening of the tunnel by Swellex rock bolts (4 to 5 m long) reduced the excavation cycle time considerably. A minimum excavation cycle time achieved was about 11 hours in a tunnel face having 3 km long lead. It is worth to mention that this type of rock bolts have been used for the first time in Garhwal Himalayas.

Swellex rock bolts

Why Swellex Rock bolts ?

The foremost criterion to prefer the Swellex rock bolts is the predominance of jointed, blocky, hard quartzite and expected wet conditions as it is very simple, safe and fast (2 min/rockbolt) to install these bolts compared to the conventional rock bolts, which is time consuming and laborious. Besides the time factor, it can be used in variety of ground conditions. The Swellex

bolts provide immediate active rock support, expanded to its full length gives friction and mechanical interlock using primary and secondary contact stress thereby providing high load bearing capacity and have ability to let rock move, thereby redistribute rock stresses in contrast to the conventional grouted rock bolts which may break when exposed to high rock stresses. As most of the conventional rock

Rock bolt installation

bolts are not resistant to corrosive environment, Swellex rock bolts coated with corrosion protection were found to be a better option.

Fig. 3: Swellex rock bolt

How Swellex works?

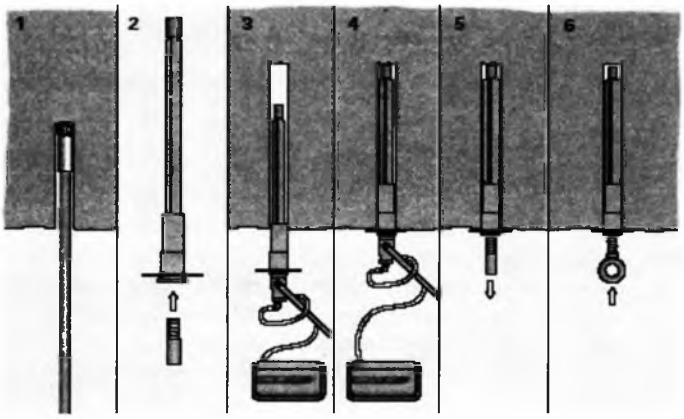
Swellex is a friction-type rock bolt, which uses the friction between the rock surface in the hole and the bolt. This friction permits small movements in rock, often experienced after blasting, to happen without adverse effects. Such movements release the stress and the rock mass become stable. Grouted bolts may break when exposed to high rock stresses.

The Swellex bolt is manufactured from folded thin wall steel tube, which is deformed in a milling process to the special Swellex shape. The tube's diameter is then reduced from 41 mm to 28 mm. Both the ends of the tube are closed by sleeves welded to the bolt. A hole is drilled in one of the sleeves to connect the internal cavity (Fig-3). The 28 mm Swellex bolt is inserted into the 35-38 mm diameter borehole by hand, using special installation arm which is equipped with a chuck that matches the Swellex sleeve. Once the Swellex is inserted into the hole, the operator presses the trigger handle and under high pressure water is pumped into the deformed tube profile. The pressure up to 300 bar expands the bolt to fill the hole completely. The water pressure is released automatically and signals that the installation has been correctly carried out. The Swellex bolt remains firmly squeezed in the hole and fits into the irregularities of the borehole, where it stays even after a pull-out test and builds-up a firm arch around an opening like tunnel (Fig-4). The whole process right from drilling

Fig. 4: Arch Building After

to installation takes only 2 minutes. A sequence of installation is depicted in (Fig-5).

In HRT of Maneri Bhali Project (Stage II) pull-out tests were carried out at selected locations applying a force of 16.5 to 17.0 ton. At these loads, Swellex bolts were found to be intact and in position.



1. Drill the hole
2. Mount the inflation adapter
3. Connect the chuck to bolt
4. Inflate the bolt
5. Dismount the adapter
6. Mount the eye-bolt/ face plate

Fig. 5: Installation Sequence

Benefits of using swellex rockbolts

A comparative study of progress achieved in HRT before and after the introduction of 'accelerated approach' including Swellex rock bolts indicated that there has been a significant increase in the average monthly progress which enabled to speed up the HRT excavation. Average monthly progress in one HRT face was of the order of 30 m prior to 1991, which increased to 65 m after implementation of the 'accelerated approach' in HRT excavation. A maximum of 186 m could be achieved in face II of HRT in the month of April 2004. The details of progress of face II, i.e. u/s face from Dhanari Gad Adit junction is given in Table-2.

Table 2: Progress Achieved in Face-II

Months	Excavation in m	Average monthly excavation in m
January- June 2003	434	93.22
July- December 2003	351	
January- June 2004	924	
July- December 2004	559	
January- March 2005	249	

This clearly suggests that without an 'accelerated approach' overall completion of HRT excavation would have been delayed abnormally thus affecting the completion of the project.

Conclusions

Swellex rock bolts are unique in providing instant reinforcement action in hard and soft rock tunneling where, time is a crucial factor as they are fast to install. They hold the preference over conventional rock bolts, which are time consuming and are laborious to install.

- Swellex rock bolts strengthen the rock mass through a combination of friction and mechanical interlock at the rock-bolt interface.
- In HRT excavation of Maneri Bhali Project Stage-II, by using these bolts for tunnel support, excavation was speeded up and time-over run was avoided.
- This 'accelerated approach' has also helped to avoid cost over-runs to some extent.