02 Jun 1988, 10:30 am - 3:00 pm

A Case History of Tehri Tunnels

B. Prabhakar
Central Mining Research Station Unit, Nagpur, India

J. L. Jethwa
Central Mining Research Station Unit, Nagpur, India

B. Singh
Central Mining Research Station Unit, Nagpur, India

Proceedings: Second International Conference on Case Histories in Geotechnical Engineering, June 1-5, 1988, St. Louis, Mo., Paper No. 2.15

A Case History of Tehri Tunnels

B. Prabhakar
Scientist, Central Mining Research Station Unit, Nagpur, India

B. Singh
Director, Central Mining Research Station Unit, Nagpur, India

J.L. Jethwa
Assistant Director, Central Mining Research Station Unit, Nagpur, India

SYNOPSIS : Tehri Dam Project, a multi purpose river valley project, is being constructed in Garhwal, Himalaya. The project consists of a 260 m high earth and rock fill dam with a clay core, four diversion tunnels each of 11 m finish diameter, four head race tunnels each of 8.5 m finish diameter and two underground powerhouses cavities each measuring 180 m long, 49.5 m high and 21.5 m wide. The project is located near the district headquarters of Tehri in the state of Uttar Pradesh. The rock masses in the project area are fragile, tectonically active and geologically disturbed. The terrain is rugged and inexcessible and therefore preclueds thorough geotechnical investigations for the disign of the cavern. The diversion and the head race tunnels were therefore used to conduct geotechnical investigations with the purpose of collecting geotechnical data for the design of two caverns. Goodman Jack tests were used to estimate the modulus of deformation of the rock masses. Load cells and tape extensometers were used to monitore the support pressure and the tunnel closures. The modulus of deformation varied from 0.18 to 0.32 kg/cm.sq. x 10^5. Tunnel closures were about 0.3% of the tunnel size. The support pressure stabilized within three months of excavation and the measured support pressures varied between 0.16 and 1.14 kg/cm.sq. This geotechnical data indicate that the rock masses behaviour was elastic in nature and the cavern could be designed without much difficulties.

INTRODUCTION

The Tehri project is the first multi-purpose development scheme being constructed in the Garhwal Himalayas for utilising the surplus monsoon waters of river Bhagirathi, a principal tributory of the mighty Ganga. The project, located in Tehri district of the state of Uttar Pradesh, envisages the construction of a 260 m high earth and rock fill dam with a claycore and an underground powerhouse of 2000 MW capacity to be built in two stages with an installed capacity of 1000 MW in the first stage. The layout plan of the Tehri dam project has been shown in figure 1. The first stage complex shall have conventional turbines and the second stage shall have reversible machines housed in a separate cavity at a comparatively lower setting. A balancing reservoir shall be created by constructing a 85 m high Koteshwar dam, about 20 km downstream of the Tehri dam project.

The project when completed will create a live storage of 2615 million cubic meters and provide irrigation to 270 thousand hectares of land and generate 2900 million units of power annually at 90% water availability, besides other benefits like moderation of floods, development of tourism and generating employment opportunities. The estimated cost of the first stage is Rs.1066 crores as on January, 1983.

The underground works mainly comprise of four diversion tunnels of 11.00 m diameter (two on each bank), four head race tunnels of 8.5 m diameter on the left bank of the river Bhilangana and the underground powerhouse complex. The diversion tunnels of 11.00 m diameter horseshoe shape are designed to pass a construction stage flow of nearly 7,500 cumecs and flood discharge of 7300 cumecs corresponding to a flood discharge of 12850 cumecs for a 1000 year return period. The two right bank diversion tunnels of 1298 and 1429 m length have already been constructed and the two left bank diversion tunnels of 1778 and 1774 m length are in an advanced stage of construction. The four head race tunnels of horseshoe shape take off at the left flank of the reservoir. Two head race tunnels will convey the water to the four machines of stage I powerhouse and the other two head race tunnels will convey the water to the stage II machines. Construction of the machine hall cavities has not begun yet. The paper describes the geology of the project area, the details of various underground excavations, details of instrumentation results and the geotechnical investigations. Estimated values of tunnel deformations from elastic analysis have been compared with measured values in the field.

GEOLOGY

The rock formations encountered in the tunnels are the phyllites of Chandpur series. The phyllites are generally banded in appearance, the bands composed of argillaceous materials. Based on the lithological character of the rock masses and the varying magnitude of tectonic deformation suffered by them, these have been broadly classified as phyllites of grades I, II and III. The rock masses of grade I are the most competent. These are predominantly arenaceous, massive in character and distinctly

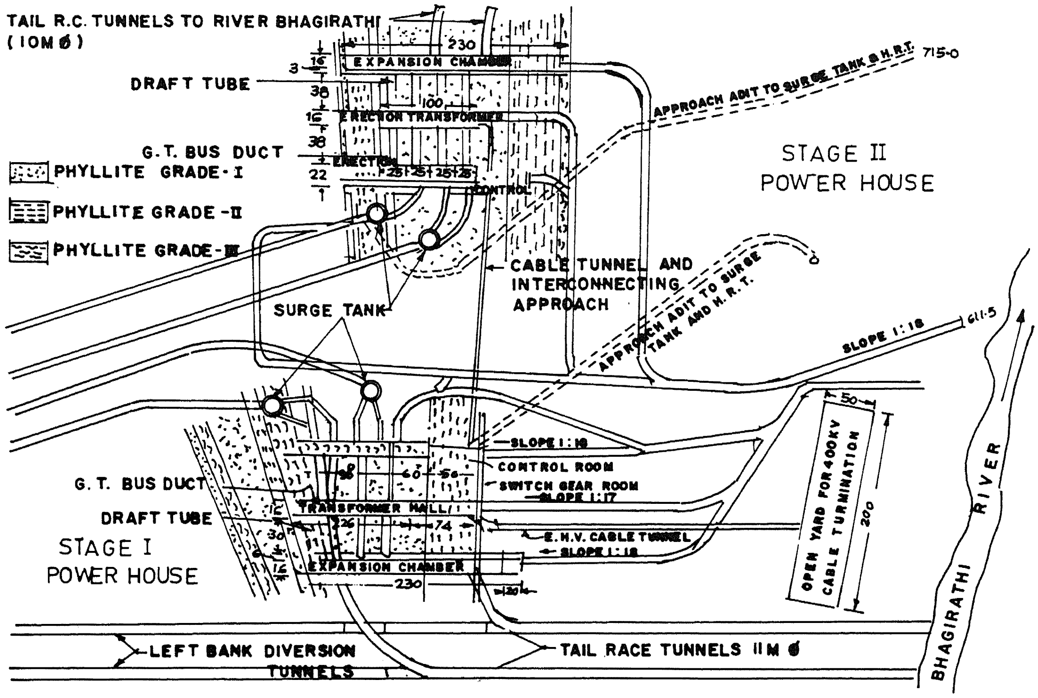

Fig. 1 Layout Plan of Tehri Dam Project

jointed. Rock masses of grade II are banded due to rapid alteration of arenaceous and argillaceous materials. The rock masses of grade III are the weakest formations and are mainly composed of the argillaceous component with lesser amount of arenaceous material. The three grades of the phyllites are interbanded and show gradual change from one grade to another along the strike direction.

GEO-TECHNICAL INVESTIGATIONS

The geo-technical investigations are being conducted to study the behavioural aspects of the different rock units, their probable mode of interaction with various engineering structures and the state of stability of the underground structures vis-a-vis the geological defects.

The process of geotechnical investigations had been initiated since the inception of the project and is being carried out contamporaneously with the construction of the various structures such as diversion tunnels, head race tunnels and approaches to the powerhouse cavern. The following studies are being conducted in the different underground openings of the project complex.

Geo-technical Tests

The Geo-technical studies consist of determination of shear strength parameters, permeability and groutability tests, deformation modulus tests and laboratory tests to find out the tensile, the shear and the compressive strength and Possion's ratio.

Deformation modulus has been determined by both direct tests and by the rock mass classification approach. For direct tests, plate jack and Goodman jacks are commonly employed. Plate jacking test has been used to determine the deformation modulus in exploratory drifts. This technique has been found to be inferior in relation to the Goodman jack test method. The later has therefore been used recently to determine the deformation modulus values from tests conducted in the tunnels. The tests were conducted in the NX size bore holes. The pressure was applied in cycles of 100, 200, 250, 500 and 700 kg/cm^2. Pressures-deformation characteristics are given in figure 2.

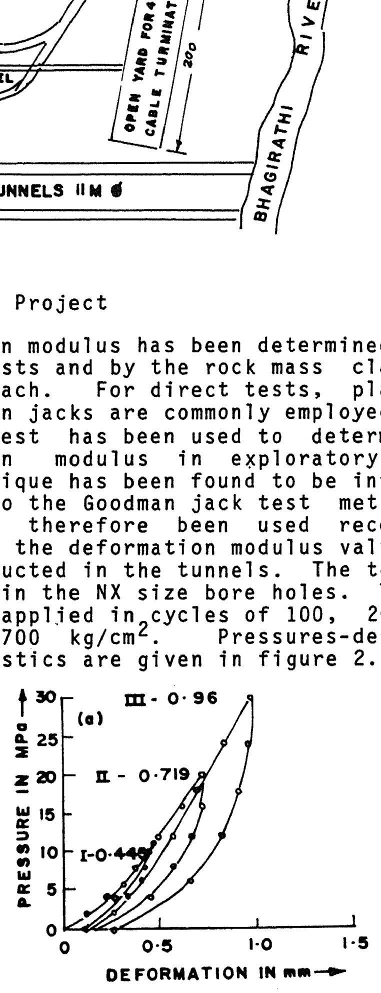

Fig. 2 Load Deformation Characteristic in a Typical Goodman Jack Test in HRT-1, ch.223.07 m, phyllites

Rock Mass Behaviour and Support Pressure

Bieniawski (1973) proposed a rock mass classification for predicting rock mass behaviour and

Table I

Derformation Modulus by Various Techniques in $Kg/Cm^2 \times 10^5$

Sl.No.	Type of Rock	Plate Jack Test	Goodman Jack	Rock Mass Classification	Recommended Value
1.	Grade I	0.68	0.06-0.570 (0.32)	1.30	0.30
2.	Grade II	0.18-0.57 (0.38)	0.046-0.385 (0.21)	0.43	0.20
3.	Grade III	0.10-0.39 (0.25)	0.025-0.345 (0.18)	0.18	0.15

Note : Figures in bracket give average values.

Table II

Comparison of Estimated and Observed Support Pressure in Kg/Cm^2

Sl.No.	Type of Rock Mass	Estimated Support Pressure				Observed Support Pressure (40 days)	Recommended value (Kg/Cm^2)
		Terzaghi's Rock Load Tables (L.T.)	Barton's Approach L.T.	Barton's Approach S.T.	Wedge Theory		
1.	Grade I	0.0-1.4	0.80	0.40	-	0.16-0.42	1.0
2.	Grade II	0.0-2.8	2.10	1.30	1.75-2.00	0.52-1.14	1.5
3.	Grade III	-	-	-	-	Not available	-

a relationship between rock material and rock mass deformation modulus. The deformation modulus with the help of this technique has been determined on the basis of the information available so far. Table I gives the range of values of deformation modulus determined by different techniques.

Various techniques are applied for the determination of support pressure. Empirical approaches of Terzaghi (1946) and Barton et al (1974) have been used for the determination of support pressure for tunnels. Sometimes a wedge of rock which may get loosened in the crown and may sit on the supports. Support pressure has also been estimated from the Wedge theory. Estimated and observed support pressures have been shown in Table II.

SEQUENCE OF CONSTRUCITON AND SUPPORT SYSTEM

Left Bank Diversion Tunnels

Excavation of diversion tunnels T-1 and T-2 were planned from both inlet and outlet ends. The inlet portal was established in October 1979. However, the hill slopes at the outlet portal were very unstable and the work was delayed due to a huge landslide near the outlet portal which occurred in the year 1980. The outlet portal therefore could be established only in 1981.

The excavation has been done by heading and bench method employing the conventional drillng and blasting technique. The pull varied from 2.0 m to 2.5 m. The consumption of explosive was of the order of 0.7 kg/cum of the excavated rock mass. Steel sets of ISMB 300 mm supported on wall brackets placed at springing level were used where the site conditions warranted the use of permanent supports.

Right Bank Diversion Tunnels

The inverts of diversion tunnels T-3 and T-4 at the outlet are at RL 600 m and 603 m respectively. Thus there tunnels negotiate a drop of 6 m. Tunnel T-3 is straight in its entire length, while the tunnel T-4 traverses a horizontal curve of 78^o after being straight in the first 28 m length. The remaining length of the tunnel is straight. For the early completion of these tunnels, the construction was taken up from both ends. The supporting system consisted of RSJ 300 x 140 steel ribs 600 mm centre to centre and M75 concrete backfill. The redistribution of stresses in the rock mass around the excavated cavity in this zone has taken place within about 3 months of the blasting and then a state of equilibrium had been reached. A record progress of about 800 cubic metre of excavation per day was obtained.

DEFORMATION MODULUS

The data collection process is going on with the construction of various components of the project. The deformation modulus of all the three grades of the rock masses have been determined by different techniques (Table I). The plate jacking test seems obsolete and the data collected may not be used for design purposes. Results of the Goodman jack tests have been accepted for design. About 130 tests have been performed, mostly in the tunnels (under pressures varying between 80 to 600 kg/cm^2). The design pressures may not be more than 40 kg/cm^2 hence the values were calculated at this pressure.

INSTRUMENTATION

Construction stage instrumentation was undertaken in the tunnels to monitor the behaviour of the rock masses surrounding the cavities by the Central Mining Research Station, Dhanbad. Load cells had been installed to measure support loads. Tape Extensometer was used to measure tunnel closures. For this purpose closure bolts had been installed in all the tunnels randomly. At a few selected test-sections both closure bolts and load cells were installed.

In the right bank diversion tunnel T-4, one test-section was established between chainages 614.50 m and 615.30 m with mechanical type of load cells. In the left bank diversion tunnel T-1, one test-section at ch. 083-84 m was established. Mechanical type load cells were installed. In the head race tunnel T-3, one test-section was installed at ch. 828-829 m. Vibrating wire and mechanical type load cells were installed. Typical closure-time and load-time graphs are shown in figures 3 to 4 respictively for this test-section. The theoretical values are also shown in these figures.

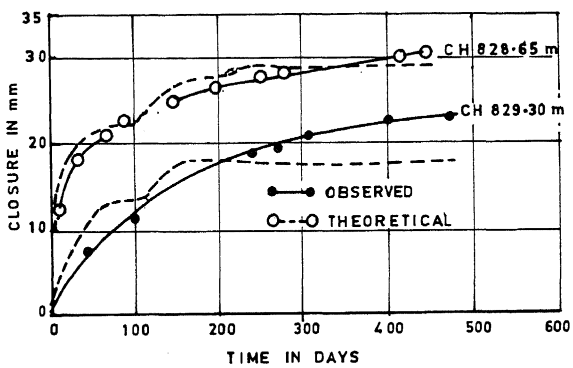

Fig. 3 Closure-Time Relation in HRT-3 (Grade III phyllites)

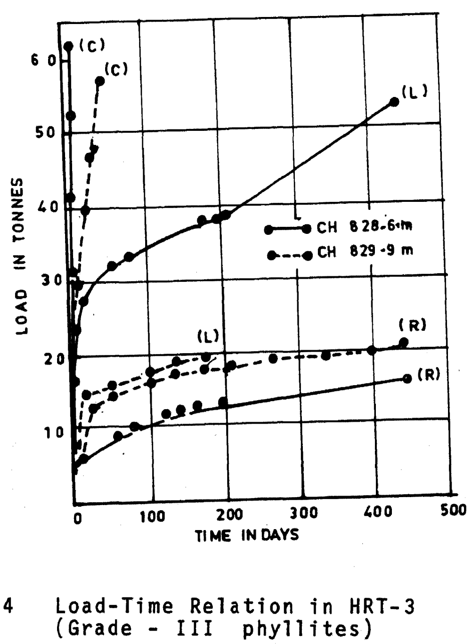

Fig. 4 Load-Time Relation in HRT-3 (Grade - III phyllites)

Tunnel Closures

The measured tunnel closures are close to the predicted values (Fig.3). The maximum value of about 30 mm works out to the only 0.3 per cent of the tunnel size and is considered due to the elastic relaxation of the rock mass surrounding the tunnel openings.

Support Pressure

Support pressures calculated by the wedge theory, Terzaghi's rock load table and Barton's method have been compared with measured values (Table II). The support pressures are very low. It can be seen that the short-term support pressure estimated by Barton's approach are close to the measured values.

CONCLUSIONS

The instrumentation data has shown that both the tunnel closures and the support pressures are very low. These can be cosidered due to elastic relaxation of the rock mass surrounding the tunnel openings. Grade I and grade II phyllites can, therefore, be considered competant to locate the powerhouse cavern.

The measured support pressures for 40 days compares favourably with the short-term values estimated by Barton's method. This would suggest that the short-term support pressure for the cavern may be calculated by this approach provided that the Q values are estimated from the full sized cavern.

REFERENCES

Barton, N, Lien, J. and Lunde, J (1974), "Engineering Classification of Rock Masses for the Design of Tunnel Supports" Rock Mech. Vol.6, pp 189-256.

Bieniawski, Z.T. (1973) "Engineering Classification of Jointed Rock Masses", Trans. S, Afr. Instn., Civil Engineers, Vol.15, pp 335 - 342.

Bieniawski, Z.T. (1974), "Geomechanics Classification of Rock Masses and its Application in Tunnelling' Proc. 3rd. Int. Cong. Rock Mech., ISRM, Denver, Vol. IIA, pp 27-32.

Jethwa, J.L. Dube, A.K. and Singh, B. (1978), "Rock Mechanics Instrumentation for Tunnels in India" Tunnels and Tunnelling, Sept, pp 63-66.

Terzaghi, K (1946), "Tunnelling with steel supports" Commercial Shearing and Stamping Co. Youngstown, Ohio, USA.