Intricate Problems Faced in Finalising the Layout for Augmenting the Capacity of Palllvasal Hydroelectric Project, Idukki District, Kerala

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Abstract

The Pallivasal Powerhouse with an installed capacity of 37.5 MW was commissioned between 1940 and 1952 in stages. Kundale and Madupatty reservoirs located at the upper reaches of Mudirapuzha river, a tributary of Periyar river provide the storage. The discharges are diverted into a 3.1 km long power tunnel at R.A. head works at Munnar. Other components include, a surge shaft, four number of penstocks and a surface powerhouse. The Project was constructed when the hydro-power development in the country was in its infancy.

The water conductor system of the Project is facing certain problems. The water cushion available at the intake of power tunnel is very low and at times it is risky to operate. There was scope for having an additional powerhouse of 60 MW as surplus water was available. However, there is no possibility of raising the height of the weir as the site is surrounded by private lands, hotels and National Highway. Hence, an alternative water conductor system with tunnel intake at lower level for feeding both old and new powerhouses was planned. When a new water conductor system was designed, no problem was faced in finalising the power tunnel alignment but, penstocks was a challenging task.

The existing penstocks faced problems in 1944 between anchor-3 and 4 due to soil creep when only two pipes were there. In 1961, after the monsoon, the penstocks were found deflected horizontally by about 23.5 cm from centre line. Further disturbance was noticed in 1964 and since then no movement was reported. Geological investigations carried out in the distressed zone indicated that the thickness of overburden Is 23 m and 28 m at anchor- 3 and 4 locations respectively and fresh migmatitic gneiss is available only at deeper levels. The overburden consists of clayey soil, scree and hill out-wash material and boulders. The slope is gentle and the affected zone forms shoulder portion of the ridge. The investigations revealed that mass movement of the overburden due to creep might have caused the distress. No major remedial measure was undertaken as advised by the experts and the powerhouse is functioning with the penstocks in the same condition.

Under the circumstances, laying of additional pipes to feed the new powerhouse by the side of the existing penstocks was considered risky due to instability of the ground. The narrow strip of KSEB land that accommodates the penstocks is surrounded by private tea estates. Investigations were carried out for alignments away from the risky zone through tea estates and found to be favourable. But, anticipated problems in land acquisition forced the KSEB to seek alternatives. Underground pressure shaft for the entire length would be uneconomical as the horizontal limb would be too long. At this stage GSI was approached for resolving the vexed problem.

When the project area was thoroughly examined, it was found that KSEB owns a sizable land at Mincut Colony located midway of the penstock route which is suitable for locating the exit portal of pressure shaft. A break in slope at the Colony created a favourable topography for providing the cover for tunneling. Finally, an underground pressure shaft for crossing the unstable reach and penstock for rest of the length was proposed by GSI. This worked out to a 355 m long pressure shaft inclined at 45° followed by a 495 m long pressure tunnel and the surface penstock for 1.5 km. The project layout was finalised on the same lines by KSEB and construction in the name of 'Pallivasal Extension Scheme' is in progress.

Geological Survey of India

Introduction

The Kerala State Electricity Board (KSEB) proposed the Pallivasal Extension Scheme to augment the installed capacity of the existing Pallivasal Hydroelectric Project by putting up an additional powerhouse of 60 MW. The new Scheme also intends to replace the existing water conductor system with a new one. At present, the maximum power that could be generated is only 32.5 MW from the existing powerhouse though the installed capacity is 37.5 MW, due to limitation in carrying capacity of the system. On commissioning of the new Scheme, full utilization of installed capacity of the existing Project also could be achieved. The Scheme is planned with the storage facility of existing Kundale and Maduppatty dams and diversion facilities at the R.A. Headworks near Munnar.

At present the tail waters of the existing Pallivasal Project and spill from R.A. Head works are being pumped into Sengulam Reservoir to feed Sengulam Powerhouse (21.25 MW). But, the present Scheme is planned in such a way that the tail waters of the proposed powerhouse could be diverted to Sengulam Reservoir by gravity flow (Fig. 1). On completion of the proposed Scheme, the existing power tunnel, surge shaft etc. shall be plugged and penstock dismantled.

Regional geological setting

The project is located in Western Ghats in an Archaean metamorphic terrain with charnockite, migmatite, migmatitic gneiss and granite as the predominant rock types. Gneissosity trends WNW-ESE and dips at steep angles towards NNE. The ENE-WSW oriented Maduppatti Dam Lineament is located 6 km north of the proposed powerhouse (GSI & ISRO, 1994). Absence of any major lineament/fault in the project area and orientation of the power tunnel largely at right angles to the regional foliation trend are the favourable geological features. Erratic patten of weathering in the area and huge thickness of overburden at the inlet area of power tunnel are considered as adverse geological features.

Origin of the scheme

Existing Pallivasal, constructed in nineteen thirties when the hydel development in India was in its infancy is the first Power Station of Kerala State. The Project has faced certain unforeseen problems on commissioning. The water cushion available at the intake of power tunnel is very low as the tunnel was constructed at a shallow depth and at times it is risky to operate the powerhouse. Raising the height of the diversion weir at R.A. Head works is ruled out as it is surrounded by private lands, hotels and National Highway. Hence, certain quantity of water is allowed to spill for maintaining the optimum level while operating the powerhouse. The spilled water and the surplus water available can feed an additional powerhouse of 60 MW. Hence, an alternative water conductor system with a larger power tunnel with its intake at lower level for feeding both old and new powerhouses was planned (DPR of the Project).

Geotechnical problems faced in finalising the layout

When a new water conductor system was designed, no problem was faced in finalising the power tunnel alignment but, penstocks was a challenging task. The machines in existing powerhouse were commissioned between 1940 and 1952 in stages. The project faced problems since beginning due to distress noticed in penstock between Anchor 3 and 4 in 1944 when only two pipe lines were laid. In 1961, after the monsoon, the penstocks were found deflected horizontally by about 23.5 cm from center line. Cracks have developed in both the abutments of the road bridge (NH 49) under which the penstocks cross the road. Some of the saddle supports between Anchor 3 & 4 were also found damaged. Further disturbance was noticed in 1964 and since then no movement was reported. Geological

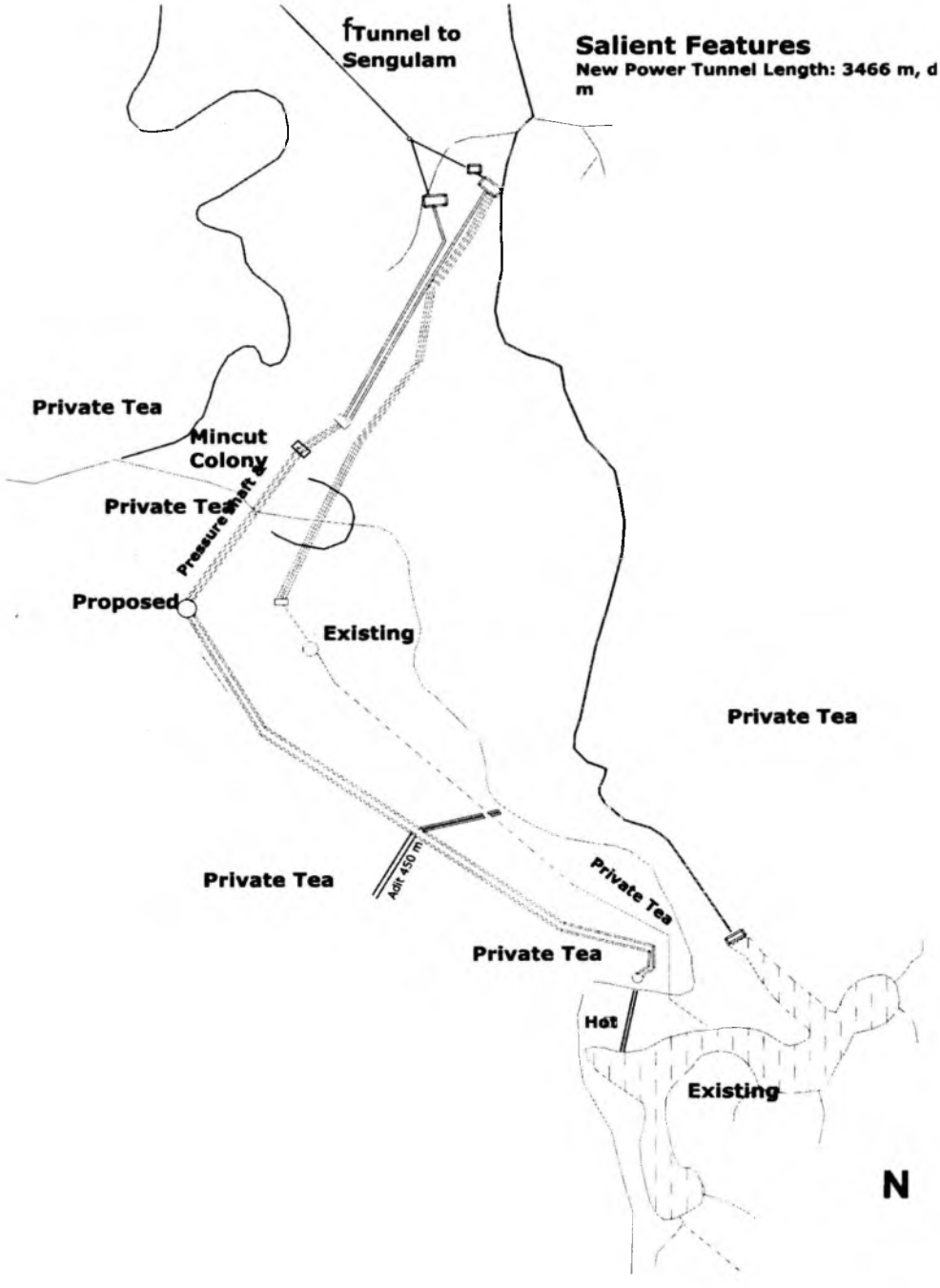

Fig. 1. Layout Map of Pallivasai Extension Scheme

investigations carried out in the distress zone indicated that fresh migmatite and migmatitic gneiss are available only at deeper levels of 23 m and 28 m at Anchor 3 and 4 locations respectively. The overburden consists of red clayey soil, scree, hill out-wash material and boulders (Rajagopalan, 2002). The slope is gentle and the affected zone forms the shoulder portion of the ridge. Based on the geological studies it was opined that the

mass movement of the overburden due to creep might have caused the distortions. The problem was studied in detail by experts but, no major remedial measure was undertaken. The powerhouse is functioning with the penstocks in same condition.

Alternative layouts studied

As already stated, drawing an alignment for the new penstocks faced several hurdles. Initially, laying of penstock pipes along side of the existing ones was thought of. In view of the soil creep occurring between existing anchor 3 and 4, the idea was dropped and KSEB studied an alignment running parallel to the existing penstocks 300 m southwest (Pitchai Muthu, 2006). The alignment was explored by geophysical survey and drilling of 9 boreholes. Though geological setting was not adverse to the proposal, penstock alignment passing through private tea estate was a hindrance as problems were anticipated by KSEB in land acquisition. Underground pressure shaft for the entire length would be uneconomical as the horizontal limb is too long. At this stage GSI was approached for resolving the vexed problem.

Solution offered by GSI

The entire layout was studied in detail to find a solution to the problem and also to improve the layout with geotechnical inputs. For the purpose, the water conductor system was divided in to power tunnel and penstock segments.

Power tunnel

In the layout proposed by KSEB, the sill level of power tunnel at intake was proposed at El. 1442 m against El. 1448.3 m of the existing tunnel, to increase the water cushion. The alignment of 3466 m long and 3.5 m dia power tunnel was drawn at about 300 m away from the existing tunnel parallelly on its right side. It was found to be taking a longer route, presumably to keep it away from the existing tunnel to avoid any damage to it during excavation. However, taking advantage of the excellent quality of rock mass exposed (migmatite and charnockite) all along the ridge and its high strength parameters, GSI recommended an alignment for new tunnel closer to the existing one with a gap of only 100 m (Pitchai Muthu, 2006). This proposal shortened the length of the tunnel by about 430 m. Accordingly, the surge shaft was also relocated in the proposal. However, in the final layout, KSEB stuck to its stand.

Adit to power tunnel

A 450 m long adit to power tunnel was proposed KSEB from the right side (northwest) of the existing power tunnel (Lakshmi stream side). An exploratory borehole drilled at the proposed portal location established the thickness of the overburden as 12 m whereas, on the southeastern side (NH-49 side) massive rock outcrops are seen all along the ridge. Besides, the side is easily accessible from the National Highway. But, it has to cross the existing tunnel. With a calculated risk, it was recommended to shift the adit to the other side of the ridge and proposed to cross the existing power tunnel below a rock cover of 20 m which was felt adequate considering the quality of rock mass (Pitchai Muthu, 2006). This proposal was incorporated in the final layout. At the time of writing this paper, excavation of the 605 m long adit was nearing completion through a medium of massive migmatitic gneiss without any support. It has successfully crossed the existing power tunnel without causing any damage to it.

Penstock Alignment

Downstream of the surge shaft, there exists the problematic zone of unstable ground between existing Anchor 3 and 4. Acquiring the adjacent land with canopy of tea for laying the penstocks was also not a plausible solution. As discussed earlier, an underground pressure shaft for the entire length would be uneconomical. With no solution in hand to break the impasse, the area was thoroughly examined in map and

on ground. A sizable land of KSEB was found available in Mincut Colony abutting against the existing penstocks just downstream of the problematic zone. The Colony was active when the old powerhouse was constructed but, now only a few establishments are located there. A solution to the problem was at sight through this piece of stable land well connected by road.

A short pressure shaft to cross the distressed zone and the private tea estates and penstocks for rest of the length was the solution proposed to KSEB. A layout with pressure shaft inclined at 45° for a length of 355 m followed by a pressure tunnel for 495 m with its exit in Mincut Colony land of KSEB was prepared by GSI (Fig. 2). The pressure shaft and pressure tunnel are oriented N25°W-S25°E. The pressure tunnel exit was proposed 60 m away from the existing penstock line. The slope of the natural surface is at 25° to 30° from surge shaft to the NH-49 and from there onwards, it eases with a break in slope in Mincut Colony. This break was found ideal for locating the exit portal as it provides the natural cover for tunneling.. Downstream of the pressure shaft exit, the penstocks can be laid alongside the existing ones in KSEB land. Length of the penstocks worked out to 1450 m.

Finalisation of the layout

The project authorities examined the proposal of GSI and found acceptable prima facie. The alignment was explored by drilling five number of boreholes. The data indicated that the thickness of overburden is >20 m at the proposed portal location. Tunneling with support could start after an open-cut for a length of 55 m in overburden. The KSEB preferred a longer open-cut and fixed the exit sill at El. 1130 m (Pitchai Muthu, 2007). It was cautioned that any deeper excavation in overburden may endanger the existing penstocks.

From the geological section prepared with the borehole data, it was understood that the rock cover is insufficient to counter the internal water pressure for the entire stretch of pressure shaft and pressure tunnel. Hence, a suitable structural support with RCC lining with/or steel liner was recommended.

Finally the project was taken up for construction with a few modifications in the layout proposed by GSI (Fig. 1). The salient features of the project are as as follows :

Power Tunnel

Sill level at power tunnel intake: +1442 m

Exit Sill Level: +1428.14 m

Shape and size of the tunnel: Circular, 3.5 m dia, lined

Length of tunnel: 3466 m

Slope of tunnel: 1 in 250

Surge Shaft Size of surge tank: 7 m dia.

Top level of surge: + 1475 m

Pressure shaft cum pressure tunnel

Diameter of steel liner: 2.5 m

Concrete back filling: 50 cm thick

Steel liner thickness: 10 to 32 mm

Maximum velocity: 4.62 m/sec

Exit sill level: +1115 mm

Length of pressure shaft & pressure tunnel: 1131 m

Penstock No. I (to new powerhouse)
Diameter: 2 m outer,

Length up to bifurcation point: 1155 m

Penstock No. II (to the existing powerhouse)
Diameter: 1.6 m outer, constant

Length up to bifurcation: 1285 m

Conclusion

A socio-engineering problem which stonewalled the project was resolved by means of geotechnical investigation. The experience from the project underlines the need for a multi-disciplinary and comprehensive approach in planning and executing the projects.

References

KSEB Detailed Project Report on Pallivasal Extension Scheme, Idukki District, Kerala.

GSI & ISRO. (1994) : Project Vasundhara National Workshop Vol. ISSN 0254-0436.

Pitchai Muthu, R. (2006) : A Preliminary Geotechnical Report on Pallivasal Extension Scheme, Idukki District, Kerala. Unpublished progress of GSI for Field Season 1999-2000 & 2000-01.

Pitchai Muthu, R & Srinivasan, R. (2007) : A Pre-construction Stage Geotechnical Report on Pallivasal Extension Scheme, Idukki District, Kerala. Unpublished progress of GSI for Field Season 2005-06.

Pitchai Muthu, R. (2007) : Progress Report No.1 on Construction Stage Geotechnical Studies Carried out for Pallivasal Extension Scheme, Idukki District, Kerala. Unpublished progress of GSI for Field Season 2006-07.

Rajagopalan, G., (2002) : Post-construction Geotechnical Problems on the Penstock line, Pallivasal Hydroelectric Project, Munnar, Idukki District, Kerala. Journal of Engineering Geology, vol. XXIX, pp. 83-87.