Geological Investigations in the Development of Hydroelectric Projects

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Abstract

Geological investigation is an essential part of hydroelectric project construction. It is required right from concept to commissioning stages of the project. Encountering geological difficulties especially in Himalayan terrain had been main deterring factor. But a few examples of project construction like in case of Uri-I, Chamera-II & Dhauliganga in the Himalayan region with adequate investigation and matching design layout combined with well managed construction methodology have shown that the hydroelectric projects can be built in a span of 4-6 years period without cost & time overrun. However, there are still some grey areas in the geological assessment, especially with respect to tunnelling media under high cover reaches and in case of slope stability, wherein high cuts are involved. Engineering geologist community need to ponder over these issues and should share some good practices or methodology adopted elsewhere for the benefit of others.

Introduction

It is well known fact that geological investigation has greater importance in the overall development of Hydroelectric Projects especially in case of Himalayan terrain. Even though, India has huge hydro potential and ranks fifth in the global scenario, but a number of hydropower projects have not come up in greater numbers to the extent it should have been. The main reason is the long gestation period involved in construction of hydroelectric projects, which comes in the mind of policy makers as well as developers of the project as a great deterrent to take up hydel projects. The cost and time overruns are very common in most of the projects. Geological uncertainties are normally considered as the major reason for such delays during project construction. In view of this, emphasis is given for detailed geological investigation during project formulation and timely evaluation of geological aspects for working out matching layout or design. Of late, there are some projects built by NHPC Ltd. in this country successfully within a span of 4-6 years in Himalayas, which is otherwise considered a difficult and challenging task in the hydropower development. These Projects are Uri-I, Chamera-II and Dhauliganga located in Kashmir, Himachal and Kumaon region of Himalayas, respectively.

Examples of expeditiously built Hydroelectric Projects in Himalaya

Uri-I project is built in Pir Panjal range of Kashmir Himalaya involving a barrage to divert water from river Jhelum through head regulator, desilting basins, 0.663 km long head race canal and 10.69 km long & 8.4 m diameter head race tunnel, 103 m deep underground surge shaft and powerhouse to generate 480 MW power. Further tail water is lead through 2 km long headrace tunnel. Construction of open structures like barrage, canal in this project involved extensive excavation of fluvioglacial deposits. Underground works on the other hand negotiated jointed and sheared quartzite, metavolcanic rocks and Eocene shale. In all, this project involved about 22 km cumulative length of underground works. Apart from the routine problems like over-

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break, water seepage, loosening of rock mass, rock stress leading to fracturing of hard rock or squeezing in soft rock, heavy stress related distress in powerhouse cavern, very difficult tunnelling conditions within tailrace tunnels were also experienced during the construction stage. Nevertheless it is significant to mention that all these tunnelling works have been accomplished without installing even single set of steel rib support but only rock bolts / dowels, shotcrete & wire-mesh. In fact this is the one project, wherein swellex bolts & fibre-reinforced shotcrete have been used extensively first time in hydroelectric projects in India. In spite of encountering typically jointed, sheared Himalayan rocks and at places charged with water, no major cavity formation hampering underground works was allowed to happen which otherwise usually experienced in any hydroelectric projects. This was possible due to timely advance probing, pre-grouting of rock mass for overall strengthening. Even about 300m length of very poor graphite schist / phyllite rock having convergence tendency was negotiated in tailrace area with multiple opening & shotcrete, rock bolt based supports. This project was built on turnkey basis through Swedish-British consortium within effective construction period of about 6 years time between 1990 & 1997. This is a good example to show that efficient construction management enables minimizing construction difficulties even associated with geological features.

Chamera-II having installed capacity of 300 MW is located near Chamba in Himachal Pradesh. The project involving a 43m high concrete dam, 7.8 km long HRT, 3.6 km long TRT with underground powerhouse was built in lesser Himalayan rocks on a turnkey basis. The bedrock, mainly comprised jointed quartzite, phyllite and slates. Project construction was accomplished between year 2000 and 2004 just within 4 to 4.5 years time.

Dhauliganga project with 280 MW installed capacity has been built by NHPC between 2000 and 2005. This project consists of 56m high concrete faced rock-fill dam (CFRD) for diverting water of river Dhauliganga through 5.8 km long headrace tunnel (water conductor system) along with twin power intake, 300m long desilting basin, 95m deep surge shaft, 250m deep pressure shafts and underground powerhouse with 450m long tailrace tunnel. All these components are hosted within biotite schist. In view of very deep overburden in the riverbed portion, CFRD was envisaged wherein 70m deep plastic concrete cut-off wall has been provided through bouldery riverine deposits. Many other problems associated with geology were experienced such as massive failure of cut-slope at the spillway portion, poor rock conditions in surge shaft & pressure shaft excavations because of widely opened & highly weathered jointed gneiss rock. Construction of CFRD which is the first dam of this kind in the country enabled in avoiding deep riverbed excavation to the tune of 70m depth for conventional concrete or rock fill dam to go upto bedrock rock level. Cut-off wall having a surface area of 75000m^2 with top length of 200m was completed between Feb.' 2002 and Feb.' 2003 for this dam and had been a innovative & challenging construction methodology used in this project.

In spite of encountering geologically difficult situations, but with the deployment of modern project construction equipments such as drilling jumbo, NATM method of rock support provided in time and with better construction management, it was possible to complete these projects within schedule time and also well within the estimated cost of the project.

In comparison to earlier days, projects are now-a-days conceived in expeditious manner wherein systematic and detailed geological investigations are carried out very comprehensively for major components of the projects in a span of 1½ to 3 years period from pre-feasibility to DPR stage. Several BIS Codes have come up to standardize geological investigations and are of great help. Overall this process of investigation in comprehensive manner has helped in eliminating or minimizing geological surprises during project construction. Or else, under difficult geological set up, suitable design remedies are being worked out in advance so that it does not upset the overall construction schedule of the project. Even during construction stage, rock mass classifications by Q-system or RMR are being adopted successfully to understand the rock media. The communication gap between the engineering geologists and designers / construction engineers is reducing with the use of standard notations, classification methods etc.

Yet, there are still some more areas, especially in respect of underground works involving long network of tunnelling and high cut slopes remain geologically uncertain to the hydro power developers. These water conductor tunnels, which are generally deep seated in the mountains are not easily approachable through sub-surface investigation techniques such as geo-physical survey, drill holes or drifting etc. In this situation, only the surface geological mapping and its projection remain the only tool in overall understanding of the geological set up. Normally, qualitative assessment of possible difficulties can be made by the engineering geologists. Recent example of encountering geological uncertainty in Parbati-Stage-II project, where in rock burst situation in quartzite under high cover reach was prognosticated. Accordingly rock burst conditions are met within the said rock under 900 m to 1000 m super-incumbent cover. If any methodology exists to identify exact location of such occurrences in advance and its likely association with geological structures, it could have been a substantial help during construction of the tunnel. There is a great need to develop alternate ways to prognosticate geological features especially along long tunnels wherein designers and construction engineers can plan their schedule and estimate the cost properly in advance.

Apart from underground works, slope instability in case of high cuts in the mountainous regions during project construction is another issue, which needs emphasis. There are several instances of cut slope failures during excavation of spillway, surface powerhouse, portal establishments, dam abutments etc., which upset overall project schedule during construction. It is generally noted that cut slopes are given little importance during investigation to understand the characteristics of rock, overburden thickness. Even extent of weathering especially in jointed / sheared rock mass has lot of importance. Such information may have to be gathered through adequate number of drill holes, drifts and rock mechanic tests for providing design input. During the project construction, many a times steep slopes are adopted due to space constraints. But without matching support systems, maintaining steep slope is difficult task. Proper investigation and evaluation of proposed cut slopes would be necessary to avoid such mishaps.

Conclusion

Generally, it is noted that hydroelectric projects getting delayed are attributed and accepted due to geological reasons. But some of the above-cited projects, which are completed in time, have shown that with adequate investigation and by the proper deployment of construction equipments and better construction management, one can overcome the routine problems during the construction of the project. Delays in project construction are not only to be seen from the associated geological problems but also from the construction methodology and management. In spite of encouraging trend in construction period of hydroelectric projects, still there are some grey areas in respect of geological assessment especially associated with tunnels and high cut slopes. This brain storming session may bring out the ideas about further improvement in geological prognostication and latest techniques used in any projects to overcome geologically difficult condition.