

Lesson Learned from Hydropower Sector of Nepal and India

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Abstract: The growing global demand for electric power, particularly in Nepal and India, has accelerated the development of hydropower projects, benefiting from abundant water resources and suitable terrain. However, many projects in the Himalayas face significant challenges due to unforeseen geological conditions, leading to delays and cost overruns. Drawing on over 40 years of experience in the sector, the author highlights key engineering geological aspects crucial to the planning, investigation, and construction of hydropower projects. Topics include site selection, the choice between surface and underground structures, geological baseline reports (GBR), and geotechnical instrumentation. Through case studies, the author underscores the importance of early-stage geological investigations, proper data collection, and monitoring to avoid costly project failures. The lessons learned provide valuable insights for young engineering geologists and engineers, contributing to the successful and sustainable development of hydropower projects.

Keywords: Hydropower, Nepal, India, GBR, Geotechnical investigations.

Introduction

The increasing global demand for electric power, particularly in countries like Nepal and India, has led to the rapid development of hydropower projects. These regions, blessed with abundant water resources and steep terrain, provide ideal conditions for the construction of hydropower facilities.

However, one of the key challenges faced by hydropower projects in the Himalayas and other hilly regions is the presence of unforeseen and adverse geological conditions. These conditions can result in significant delays, cost overruns, and even failure if not properly addressed. Drawing on over 40 years of experience in the hydropower sector, the author shares insights into the engineering geological challenges associated with the planning, investigation, design, and construction of hydropower projects. By addressing these challenges early in the planning process, developers can avoid costly mistakes and ensure the successful completion of their projects.

Geological Considerations in Hydropower Projects

The first step in any hydropower project is site selection. The decision to select a particular site must be based on

careful consideration of the geological conditions. In many cases, poor site selection has resulted in significant project delays, cost overruns, and contractual disputes. For example, one of the common pitfalls during the site selection process is the failure to identify serious geological problems that could make the site unsuitable for hydropower development. These issues may include the presence of weak or fractured rock formations, unstable slopes, or areas prone to landslides and seismic activity. By thoroughly investigating these factors during the early stages of site selection, developers can make informed decisions, such as abandoning a problematic site in favor of a more geologically stable alternative.

This decision-making process is crucial, as ignoring geological problems during site selection can lead to substantial financial losses, not only from the direct costs of dealing with unforeseen geological challenges but also from the loss of revenue due to construction delays and penalties associated with power purchase agreements (PPA).

One of the key decisions in hydropower project design is whether to construct surface or underground structures. Both options have their pros and cons, and the decision should be based on a thorough understanding of the geological conditions and the potential risks.

Surface and Underground Structures

Surface structures, such as powerhouses and dams, are often preferred for their accessibility and ease of construction. However, they are more vulnerable to extreme weather events, such as flash floods, cloudbursts, glacial lake outburst floods (GLOFs), and seismic activity. These events can cause significant damage to surface structures, resulting in costly repairs, lengthy power outages, and penalties under the PPA for failure to deliver power. For instance, in the event of a flash flood or GLOF, surface structures may be washed away or severely damaged, necessitating expensive reconstruction efforts. Beyond the cost of repairs, developers must also contend with lost revenue during the downtime and penalties for not meeting power delivery commitments.

On the other hand, underground structures, such as tunnels and underground powerhouses, offer greater protection against extreme weather events and seismic

activity. While they are generally more expensive and technically challenging to construct, their resilience to natural disasters makes them an attractive option for long-term stability. The decision to go underground must also take into account the geological conditions. For instance, poor-quality rock, high water ingress, or the presence of fault zones may complicate underground construction. However, when properly planned and executed, underground structures can protect developers from the costly consequences of natural disasters and ensure uninterrupted power generation.

Challenges in Engineering Geological Investigations

During the drilling phase of engineering geological investigations, inexperienced geologists may encounter challenges in poor-quality rock formations, leading to low core recovery and inaccurate Rock Quality Designation (RQD) values. The RQD, which measures the percentage of solid core pieces longer than 10 cm in a borehole, is a crucial parameter for assessing the quality of the rock mass. If core recovery is low, it may be difficult to accurately assess the geological conditions, potentially leading to design errors and construction delays. It is essential for engineering geologists to use proper techniques during drilling and logging to ensure accurate data collection and to incorporate this data into the drilling report. This information is vital for the geotechnical and structural designers to make informed decisions regarding support systems, excavation methods, and overall project design. Another common issue is the failure to respect the stand-up time of an unsupported span during excavation. Ignoring this critical factor can lead to unexpected collapses, resulting in disputes between the developer and the contractor regarding repair work and the associated extra costs. It is essential for engineering geologists to closely monitor stand-up time during construction and to implement appropriate support systems, such as shotcrete, rock bolts, or steel ribs, to ensure the stability of the excavation. Failure to do so can result in project delays, increased costs, and potential safety hazards for workers.

Importance of GBR

A well-prepared Geological Baseline Report (GBR) is a crucial component of the feasibility study or detailed project report (DPR) for any hydropower project. The GBR serves as a reference document that outlines the geological conditions at the project site and provides a baseline for project planning, design, and construction. It includes data from pre-construction investigations, such as drilling, geophysical surveys, and laboratory testing of rock and soil samples. The GBR is not only essential for the technical team but also for lenders and banking institutions that provide funding for the project. Financial institutions are more likely to invest in projects that demonstrate sound geological planning and a clear

understanding of the technical and commercial viability of the site. The GBR should include geological mapping of the site, results of borehole drilling and core logging, rock mass classifications (RQD, GSI, etc.), identification of fault zones, shear zones, and other geological hazards, recommendations for excavation and support systems and baseline data for geotechnical instrumentation and monitoring. By incorporating all of this information into the GBR, developers can avoid costly surprises during construction and provide assurance to lenders that the project is technically feasible and financially viable.

Site investigations and monitoring

Comprehensive pre-construction investigations are essential to understand the geological conditions at the project site. This includes laboratory testing of rock and soil samples to determine their strength, permeability, and other key properties. The results of these tests are critical for designing the excavation and support systems and for determining the suitability of the site for hydropower development. In addition to laboratory testing, field investigations, such as in-situ stress testing, geotechnical instrumentation and monitoring, seismic surveys, and geophysical logging, can provide valuable information about the subsurface conditions. These investigations help engineers identify potential challenges, such as fault zones, weak rock formations, and high groundwater pressure, that could impact construction. During construction, geotechnical instrumentation is used to monitor the stability of the excavation and the surrounding rock mass. By closely monitoring these parameters, engineers can detect early signs of instability and take corrective measures to prevent failures. Regular monitoring also ensures that the project stays on schedule and within budget by avoiding costly delays caused by unexpected geological issues.

Conclusion

The successful development of hydropower projects in the Himalayan region requires a sound understanding of the engineering geological conditions and careful planning at every stage of the project. By conducting thorough site investigations, preparing detailed Geological Baseline Reports, and selecting the appropriate construction methods, developers can avoid costly mistakes and ensure the timely completion of their projects.

The lessons learned from past projects provide valuable guidance for young engineering geologists and civil engineers entering the hydropower sector. By applying these insights, they can contribute to the successful development of hydropower projects that meet the growing demand for clean, sustainable energy.