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Geotechnical Investigation and Its Challenges in Landslide Dammed Valley of Nepal Himalaya: A Case History of Upper Tamakoshi Hydropower Project

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Abstract: The natural damming of rivers by landslides is a prominent geomorphological phenomenon in the high, rugged mountains of the Nepal Himalaya. One such example is the wide valley of Lamabagar, which was formed by the landslide damming of the Tamakoshi River where the damsite of Upper Tamakoshi Hydropower Project (456MW) is constructed. Geotechnical investigations in such complex terrain are critical and typically involve multiple stages, including site investigation, soil and rock testing, modeling, empirical and mathematical analyses, field measurements, monitoring, and ultimately, the engineering design of structures. These steps are essential for ensuring stability and suitability of the site prior to construction. During the construction phase of the Upper Tamakoshi Hydropower Project, the 2015 Gorkha Earthquake caused substantial damages, triggering the need for further geotechnical evaluation of the dam site area. The primary objectives at that time were to delineate the bedrock depth on the left and right abutments as well as at the dam center and to determine the geotechnical parameters of both the rock and overburden materials. This study specifically focuses on the characterization of materials extracted from a borehole located at the left abutment. The analysis includes interpretation of assessment of surface observation, borehole data interpretation and in-situ tests. Findings indicate that a large boulder is resting over the alluvial deposits of the Tamakoshi River at the left abutment. This observation is significant for understanding the mechanical behavior and stability of the dam foundation in this type of area. The characterization of these materials provides essential input for structural design, seismic assessment, and long-term performance evaluation of the dam infrastructure.

Keywords: ***Landslide dammed valley, Geotechnical investigation, Hydropower project, Alluvial deposits.***

Introduction

Natural damming of rivers by large landslides is a prominent geomorphological process in the steep, seismically active mountain environment of Nepal. The Lamabagar Valley in Dolakha District, where the Upper Tamakoshi Hydropower Project (UTKHP) with an installed capacity of 456 MW is located, represents a classical example of a valley formed by prehistoric landslide damming of the Tamakoshi River. Such a setting presents unique geotechnical and geological challenges for hydropower infrastructure development, including heterogeneous overburden, variable bedrock depths, and complex slope stability conditions.

Geotechnical investigations in these environments are essential for ensuring the long-term stability and safety of dam foundations (Uhlir, 1998). The 2015 Gorkha Earthquake (Mw 7.8) further complicated the engineering conditions of the project area, prompting additional investigations to evaluate earthquake-induced effects and reassess foundation stability.

Methodology

A comprehensive geotechnical investigation was undertaken to evaluate the engineering characteristics of the left abutment of the dam. The program included:

- Morphological study and visual Surface observation: Identification of paleo-landslide along the left bank of Tamakoshi River around damsite area and observation of evidence of fluvial activities above 20 m uphill side from damsite area.
- Exploratory Drilling and Sampling: Boreholes drilled along the dam axis and abutments to determine overburden thickness, bedrock depth and conform whether the rock of left abutment is bedrock or huge boulder.
- In-situ: Standard penetration tests (SPT), permeability tests (Constant Head Test-CHT in overburden and Lugeon test in rock mass).

In SPT test driving was accomplished by a drop of hammer weighing 63.5 kg falling freely through a height of 750 mm onto the drive head. First, the spoon is driven 150 mm into the soil at bottom of the borehole. It is then driven further 300 mm and the number of blows (N values) required to drive this distance is recorded.

Permeability test using CHT method was carried out in the overburden deposits. The permeability is calculated as follows:

$$k = \frac{(1000 \times Q)}{5.5rH} \times 60\ cm/sec$$

Water Pressure Test (Lugeon test) was carried out by using single packer in the drill hole at 5.0 m interval. and the Lugeon Value is calculated as follows (Houlsby, 1976):

$$L_u = (10 \times Q)/(P \times L)$$

Figure 1, Scarp of paleo-landslide at the left abutment of damsite area.

Figure 2, Sub-rounded pebbles present above 20 m uphill side from damsite area.

Figure 3, At depth of 77.45 - 77.55 m, angular to rounded pebbles of alluvial deposit (schist, gneiss and granite) is extracted.

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Conclusion

In conclusion, geotechnical investigations in landslide dammed valleys of the Nepal Himalaya are inherently challenging due to heterogeneous subsurface conditions, complex geomorphology, and high seismicity. The Upper Tamakoshi case highlights the importance of an integrated, multidisciplinary approach combining geomorphological study, detailed surface mapping, borehole drilling, and in-situ testing. Observations of fluvial remnants such as sediment layers, bedrock scour marks, and boulder alignments around 20 meters above the dam site provided key insights into past geomorphic processes and prompted revisions to conventional investigation practices, particularly after the 2015 Gorkha earthquake. The study underscores the need for adaptive, site-specific geotechnical strategies to enhance the safety, reliability, and seismic resilience of hydropower and dam projects in the Nepal Himalaya.

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