Road Side Slope Stabilization Using Ground Water Management at Far-Western Nepal

Brabin Sapkota[1,*] and Manita Timilsina[2]

[1]Innovative Engineering and Management Pvt. Ltd. Kumarigal, Kathmandu, Nepal
[2]Geotech Solutions International Pvt. Ltd., Dhobighat, Laitpur, Nepal

(*Corresponding E-mail: brbsapkota@gmail.com)

Abstract: This study investigates landslide susceptibility in Nepal's Far-Western region, particularly Sudurpashchim province, where monsoon rains and rugged terrain increase landslide risks. A major landslide on the Mahakali Highway, prompted analysis using field investigations, borehole drilling, and Electrical Resistivity Tomography (ERT) to assess lithology and soil stability. Slope stability analysis shows that rainfall-induced water level rises weakened soil strength, but mitigation measures like slope benching and dewatering improved the factor of safety (FOS) from 1.20 to 2.49. Wells and horizontal drains were proposed to stabilize the area by reducing groundwater levels.

Keywords: ***Drainage wells, Horizontal drain, Geotechnical investigation, Geological investigation, Numerical analysis.***

Introduction

The Far-Western region of Nepal, particularly within Sudurpashchim province, is highly susceptible to landslides due to its rugged terrain, active geological features, and heavy monsoonal rains. As part of the geologically young Himalayan range, landslides in this area are largely triggered by natural factors, such as intense monsoon rainfall (Choi and Cheung 2013). With increasing awareness of climate change and shifting rainfall patterns, the risk of landslides in the region is expected to grow in the coming years.

A notable incident occurred around midnight on Shrawan 22, 2080, along the Mahakali Highway in Godawari Municipality-4, Kailali District. Monsoon rains triggered a significant landslide that completely blocked the highway for seven days, making it impassable for all vehicles. As a vital route connecting the highland regions to the Terai, the closure stranded hundreds of passengers and disrupted travel between the hill and Terai districts. The landslide also caused severe damage to five nearby houses, underscoring the hazards posed by rainfall-induced landslides in the region.

Methodology

This study is based on a thorough assessment of secondary data, combined with detailed field investigations, to analyze the landslide in the study area. The secondary data includes previous research, historical landslide records, and rainfall data, providing a broad context for the current study. To gain a comprehensive understanding of the site's geological and engineering conditions, performed both geological and engineering geological mapping. This mapping process helped in identifying the physical and structural characteristics of the area, such as rock types, fault lines, and slope orientations, which are critical for assessing landslide susceptibility.

In addition to geological mapping, geotechnical investigations were conducted, which included drilling two boreholes. These boreholes allowed to explore the subsurface lithology (the different layers of soil and rock) and obtain detailed information about soil properties at various depths. Key parameters such as soil composition, moisture content, and density were analyzed. Understanding the lithology is essential to determine the potential for slope failure, as certain soil and rock types are more susceptible to landslides.

To supplement the geotechnical investigation, a geophysical test known as Electrical Resistivity Tomography (ERT) was performed. As it measures the resistivity of subsurface materials to generate a profile of the area’s lithology. This method helps identify variations in soil and rock properties, water content, and possible weak zones within the landslide area that may not be easily observed through borehole data alone.

Following the collection of geological, geotechnical, and geophysical data, slope stability analysis was carried out using specialized software tools like Slope/W and Seep/W (Acharya et al. 2016). The analysis was based on the data obtained from the boreholes, including soil strength, water table position, and slope geometry. The purpose of these analyses was to understand how different factors—such as soil type, water infiltration, and slope angle—affect the overall stability of the slope and the likelihood of future landslides.

By combining the results of the geotechnical investigations, ERT testing, and slope stability analysis, the study provides a comprehensive evaluation of the landslide-prone area, offering insights into its behavior under various conditions and laying the groundwork for the development of appropriate mitigation strategies.

Results

The study found that heavy rainfall caused the water level to rise from hydrostatic conditions, resulting in a decrease in soil strength (Tiwari and Ajmera 2023). Numerical analysis was conducted under various scenarios: normal conditions, rainfall conditions, and the combined effects of rainfall and dewatering using wells. The factor of safety increased from 1.20 to 1.86 in the combined condition. Additionally, with the implementation of slope benching and dewatering using wells, the factor of safety further improved to 2.40. The proposed mitigation measures were based on the geological properties and lithology, which were analyzed using a geological cross-section and verified through borehole logs, containing of sandstone and mudstone bedding as illustrated Figure 1

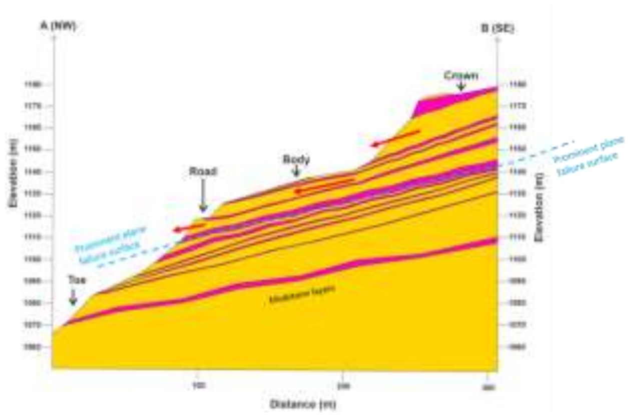

Figure 1 Geological interpretation of global plane failure scenario in the landslide area evident by lithological settings of the landslide area.

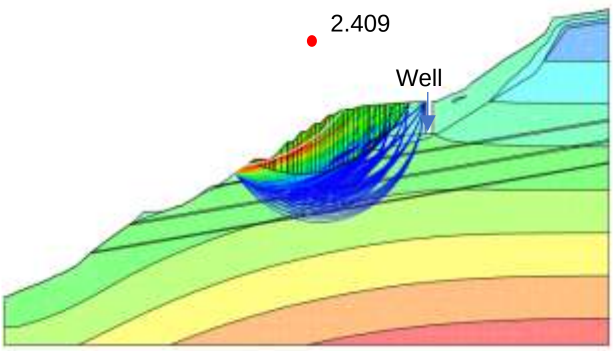

Figure 2 Obtained factored of safety after cut benching and dewatering using well. Model analysis for cut benching on valley side with rainfall and dewatering condition, FOS: 2.409.

Conclusions

The study conducted in the far-western region of Nepal, particularly in Sudurpashchim province, reveals that landslides are primarily triggered by intense monsoon rainfall and geological factors inherent to the Himalayan terrain. A significant incident occurred on Shrawan 22, 2080, along the Mahakali Highway, causing disruption and damage due to rainfall-induced landslides. The methodology involved a combination of geological, geotechnical, and geophysical investigations, including borehole drilling and Electrical Resistivity Tomography (ERT), to understand the area's subsurface properties. The slope stability analysis, using specialized software tools, highlighted that rainfall reduces soil strength and increases landslide risk.

The prevailing rock type predominantly comprises sandstone, exhibiting frequent bedding alternating between sandstone and mudstone plane. Through geological and geotechnical analyses, is deemed to have experienced failure along the mudstone plane. This failure is attributed to the impact on shear strength parameters resulting from changes in groundwater conditions and saturation in mudstone plane. According to the Electrical Resistivity Tomography (ERT) report, the ground within the landslide area is highly saturated at the time of study.

The study's results emphasize the importance of mitigation measures, such as dewatering and slope benching, which significantly improved the slope's factor of safety (FOS). The most effective strategy, combining slope benching and dewatering, increased the FOS to 2.49. These findings suggest that the landslide was largely driven by saturation of the mudstone plane, weakening the slope's stability. Dewatering wells and horizontal drains are recommended to lower the groundwater level and enhance long-term stability in the affected region.

References

Acharya, K. P., Bhandary, N. P., Dahal, R. K., and Yatabe, R. (2016). Seepage and slope stability modelling of rainfall-induced slope failures in topographic hollows. Geomatics, Natural Hazards and Risk, 7(2), 721-746.

Choi, K. Y. and Raymond W.M.C. (2013). Landslide Disaster Prevention and Mitigation through Works in Hong Kong. Journal of Rock Mechanics and Geotechnical Engineering, 5(5), 354–65.

Tiwari B. and Ajmera B. (2023). Advancements in Shear Strength Interpretation, Testing, and Use for Landslide Analysis. Chapter In: Progress in Landslide Research and Technology, 2 (2), 3–54.