

Integrated Engineering Geological and Geotechnical Assessment, Slope Stability Analysis at the Building on Landslide, Nagarkot, Nepal

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Abstract: Rainfall-induced slope instability at a hotel construction site, Nagarkot, was investigated following a landslide triggered by approximately 16 hours of continuous heavy rainfall on July 6, 2024. The study integrates engineering-geological mapping, topographic surveying, geotechnical investigation, infiltration testing, laboratory analysis, borehole data, and limit-equilibrium slope-stability analysis to characterize the unstable slope and assess mitigation measures. The investigation covered approximately 11,000 m² and included total-station surveying, field-density and portable DCPT testing, infiltration measurements, geological mapping, grain-size analysis, moisture content, specific gravity, Atterberg limits, and direct-shear testing. The slope comprises gneissic bedrock overlain by variable colluvium and silty soil, with springs, erosional gullies, cracks, a roadside canal, and damaged retaining structures contributing to instability. Laboratory results indicate moisture contents of 13.37–56.97%, specific gravity of 2.60–2.68, cohesion of 4.58–9.03 kPa, and friction angles of 21.69°–27.14°, with an average infiltration rate of 0.0002 cm/s. Morgenstern–Price analysis in commercially available software yielded FOS values of 1.025 under dry conditions, 1.012 under probable groundwater conditions, and 0.472 under seismic loading. The proposed combined reinforcement/nailing and reinforced-soil-wall system increases the FOS to approximately 1.9, demonstrating improved stability and emphasizing the need for integrated structural reinforcement, drainage, erosion control, and long-term monitoring.

Keywords: Landslide, Engineering geology, Geotechnical investigation, Slope Stability, Infiltration, Morgenstern–Price.

The study area is situated in Mandandeupur and Shankharapur municipalities of Nagarkot, Kavrepalanchok District, Bagmati Province, approximately 32 km northeast of Kathmandu. The reported coordinates are 27°43'42.89"N and 85°31'26.87"E. The area lies in a mountainous setting with elevations in the study locality ranging from 1809 to 1894 m. Gneiss is exposed in the middle and western portions of the landslide, while colluvium and variable silty to sandy materials occur across the slope. The mapped site contains springs, erosional gullies, cracks, a canal along the road, a damaged gabion wall at the toe and a plum wall below the resort building.

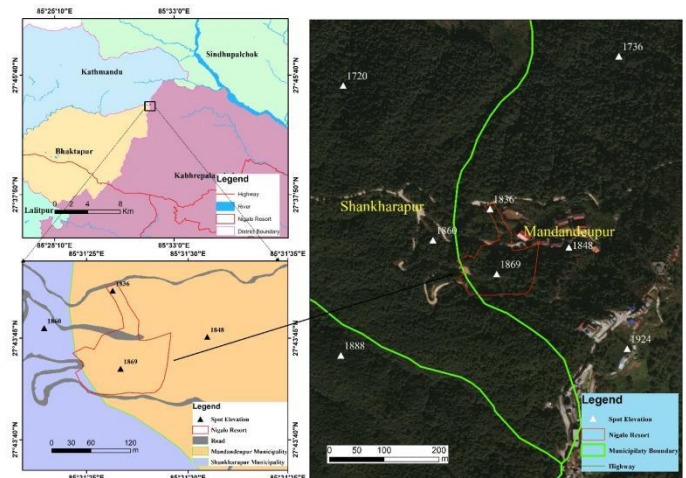


Figure 1, Location map of the study area

Introduction

Landslides in the middle hills of Nepal commonly result from the interaction of steep terrain, weathered geological materials, discontinuities, rainfall infiltration, surface runoff, groundwater and human modification (Tiwari et. al. 2024). At the slope in the study area at Nagarkot, a prolonged rainfall event triggered a landslide that damaged an existing gabion wall and created a significant stability concern for the resort and its surrounding facilities. The investigation was undertaken to characterize the engineering-geological and geotechnical conditions, identify factors controlling instability, assess present slope stability and evaluate practical stabilization measures.

Methodology

The study integrated desk review, field investigations, laboratory testing, and analytical modelling. Geological maps, satellite imagery, historical records, and climatic data were reviewed. Total-station surveying covered approximately 11,000 m², supported by engineering-geological mapping, density measurements, DCPT, infiltration tests, and soil sampling. Laboratory tests included grain-size distribution, moisture content, density, specific gravity, Atterberg limits, and direct shear. Three boreholes (BH1–BH3), extending to 15 m, informed stability modelling using the Morgenstern–Price method, Mohr–Coulomb and Hoek–Brown criteria, and dry, groundwater, and seismic conditions. Mitigation

integrates slope reinforcement/nailing and a reinforced-soil wall while preserving functional building space.

Results

Engineering-geological mapping indicates that the unstable slope consists of gneiss bedrock (DMG, 2020) with a variable mantle of colluvium and silty to sandy soil. Silty gravel and gravelly sand are common, with clayey silt and poorly graded sand also present. The slope contains several erosional gullies and localized cracks, particularly toward the eastern and canal areas. These features indicate concentrated runoff, local saturation and zones of reduced ground integrity. The measured average infiltration rate of 0.0002 cm/s demonstrates that infiltration and drainage conditions require explicit consideration in stabilization design.

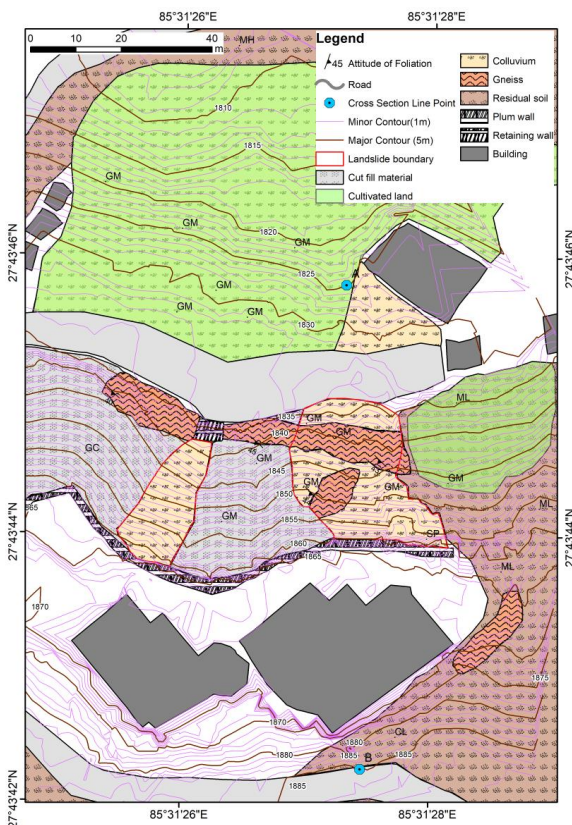


Figure 2, Site lithological map showing the distribution of geological materials.

Laboratory testing reveals significant spatial variability in the slope materials. Natural moisture content ranges from 13.37% in the eastern slope body to 56.97% at the crown, while specific gravity varies between 2.60 and 2.68. Cohesion ranges from 4.58 to 9.03 kPa, with friction angles of 21.69°–27.14°. The soils are predominantly classified as inorganic silt, including medium-plasticity silt at several locations. The crown exhibits the highest moisture content and cohesion, whereas the eastern body has the lowest cohesion, highlighting the influence of seasonal wetting on slope strength.

For the critical section at CH 0+040, the stability model considers a 90-mm grout-hole diameter, 32-mm reinforcement, 24-m reinforcement length, and 250-kPa bond strength. The overburden is characterized by

cohesion of 6 kPa, a friction angle of 26°, and unit weight of 16 kN/m³. Hard rock parameters include a unit weight of 26 kN/m³, $M_i = 28$, $GSI = 37$, disturbance factor of 1, and UCS of 32 MPa.

Unmitigated analysis yields FOS values of 1.025 under dry conditions, 1.012 under probable groundwater conditions, and 0.472 under seismic loading, demonstrating inadequate and critical stability.

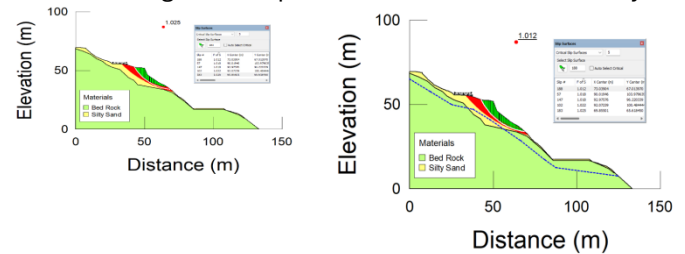


Figure 3, Reported global stability analyses for (a) dry and (b) probable groundwater conditions.

Conclusion

The investigation confirms that the building on landslide is controlled by the interaction of geological, geotechnical and hydrological factors. The slope comprises gneiss bedrock overlain by variable colluvium and silty soil, with springs, gullies, cracks and existing retaining structures influencing slope behavior. Laboratory testing shows variable moisture content and relatively low cohesion, while the average infiltration rate indicates that rainfall and drainage conditions are important components of the slope response.

The reported Morgenstern–Price analysis gives FOS values of 1.025 in dry conditions, 1.012 with the probable water surface and 0.472 for the seismic condition, demonstrating inadequate stability in the existing state. The proposed combination of reinforcement/nailing and reinforced soil wall increases the modeled FOS to approximately 1.9. Effective surface and subsurface drainage, erosion control, construction quality control and long-term monitoring are recommended as integral components of the stabilization scheme. Particular attention should be given to changes in groundwater and crack development during the monsoon period.

References

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