Rockfall Analysis for the Construction of Flexible Rockfall Barrier System at Upper Tamakoshi Hydroelectric Project

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Abstract: Rockfalls pose a significant hazard in Nepal due to its steep terrain, fragile geology, and frequent seismic activity, with risks further heightened during the monsoon season. The Upper Tamakoshi Hydroelectric Project (UTKHEP), Nepal's largest hydroelectric project, has faced persistent rockfall issues at its take-off yard since the early construction phase. This study investigates the design and implementation of a rockfall protection barrier to safeguard the project's infrastructure. A comprehensive field survey, including drone imaging and rock boulder analysis, was conducted to assess potential rockfall sources and deposition zones. The CRSP computation method was employed for rockfall simulation using GeoRock-2D software, with parameters such as boulder size, slope material, and surface characteristics. Simulation results identified optimal locations for barrier placement based on maximum energy and bounce height of falling rocks. The study highlights the importance of rockfall mitigation for infrastructure protection in Nepal's mountainous regions.

Keywords: ***Rockfall, CRSP, GeoRock-2D, Rockfall barrier.***

Introduction

Rockfall in Nepal are a significant hazard due to the country's steep, mountainous terrain, fragile geology, and frequent seismic activity. The risk of rockfalls is heightened during the monsoon season, when heavy rains saturate the soil and weaken slopes, causing rocks to detach and fall onto roads, settlements, and agricultural land. Earthquakes, like the 2015 Gorkha earthquake, also play a critical role in triggering rockfalls by loosening rock formations and destabilizing slopes. These events can lead to loss of life, damage to infrastructure, and disruptions to transportation in rural and urban areas, making rockfall management a key concern for disaster risk reduction in Nepal.

Rockfall protection barriers serve as a secondary form of defense in possible deposition zones of rock fall, such as collapsed cliffs. Upper Tamakoshi Hydroelectric Project (UTKHEP) 456 MW is the largest hydroelectric project so far in Nepal which is under completion. The take-off yard of this national priority project at Gongar has been facing rock-fall issues since its early phase of construction. In this context, Upper Tamakoshi Hydroelectric Project decided to protect the structures from future rockfall hazards using special mitigating measures. An analysis was carried out for the construction of the rockfall barrier at the take-off yard.

Methodology

A joint survey was carried out in the rockfall area and old temporary fences were inspected to check the impact observed. Drone survey was also carried out to capture the terrain information, rockfall source and deposition zone during field investigation. To assist in numerical simulation, rockfall sources were identified. Figure 1 shows the drone image and tentative area of rock fall sources. In addition to this, rock boulder survey was also carried out to identify rock sizes that can fall during a rockfall event. Figure 2 shows the different types of rock boulders found in the area and the measurement carried out, which helped us identify boulders of disc shape.

Figure 1, Drone image showing the rockfall deposition and source area including vulnerable area

CRSP computation method is used for the rockfall simulation. The input parameter used for the rockfall simulation depends on the surface characteristics of the slope. The restitution coefficient represents the surface characteristics of the slope material. Both normal and tangential restitution coefficient ranges from 0.29 to 0.9. The restitution coefficient of the material is taken from different scientific studies (Pfeiffer et al. 1989, Giani 1992). The boulder size is determined from the block analysis of the discontinuities.

Figure 2, Rock boulders measurement carried out on the slope and deposition area.

Result

Simulation of rockfall event was carried out based on field observations, measurements and notes using GeoRock-2D. The profile selected for the simulation is shown in Figure 3. Boulders are assumed as cylindrical shapes. Following are the simulation input parameters:

- Rock type: Biotite banded gneiss
- Materials used in slope: degraded rock, rock detritus, paved surface debris with vegetation and terrain/grass.

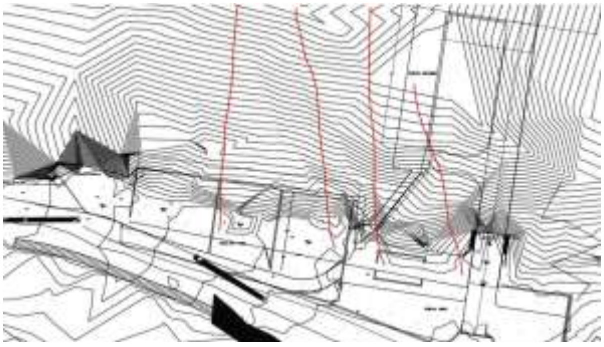

Figure 1: Selected simulation profile.

- Cylinder diameter: 0.6 m
- Cylinder height: 0.62 m
- Specific weight: 9000 kg/m^3
- Elasticity modulus: 11000 kPa

For all selected profiles, numerous trajectories were selected, and simulation was performed to determine maximum energy and bouncing height and best location to meet both criteria is selected for the position of rock fall barrier. Figure 4 shows the simulation scenarios with and without post on slope.

Conclusion

In conclusion, rockfalls pose a significant hazard in Nepal, exacerbated by the country's steep terrain, fragile geology, and seismic activity, particularly during the monsoon season. The Upper Tamakoshi Hydroelectric Project, Nepal's largest hydroelectric initiative, faces ongoing rockfall challenges, necessitating the implementation of protective measures.

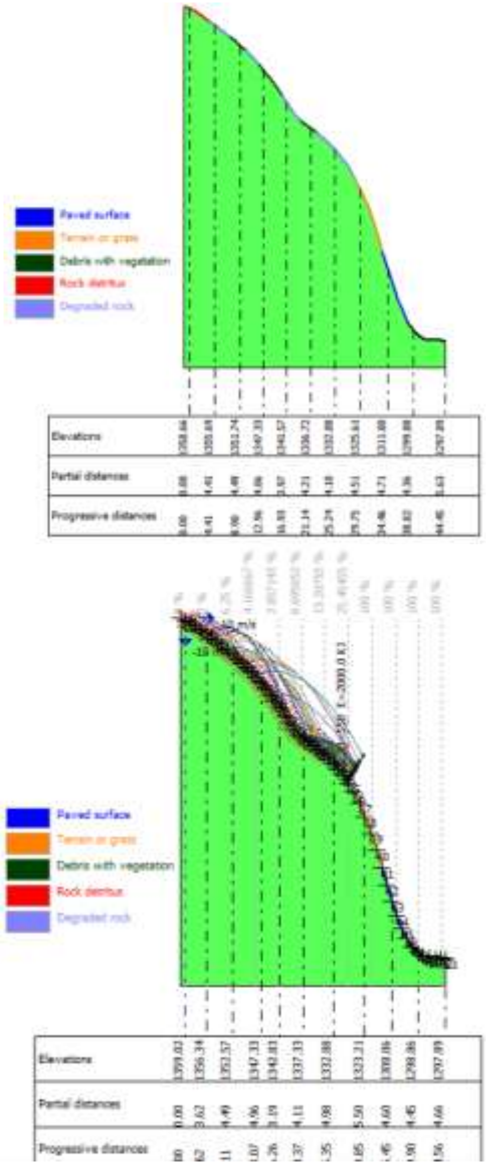

Figure 2: Simulation results on profile.

This study utilized a combination of joint surveys, drone technology, and numerical simulations to analyze potential rockfall sources and design an effective rockfall barrier at the take-off yard. The findings highlight the importance of understanding slope characteristics and boulder dynamics to enhance rockfall management strategies. The proposed barrier aims to mitigate risks, ensuring the safety and continuity of infrastructure and reducing disaster impacts in vulnerable areas.

References

Pfeiffer T.J. and Bowen T.D. (1989). Computer Simulation of Rockfalls. Environmental and Engineering Geoscience; xxvi (1): 135–146.

Giani G.P. (1992). Rock slope stability analysis. Balkema, Rotterdam. 361p.