

Engineering With Cut Rock Slopes on Highways: Geotechnical Perspective

Mahendra Singh^{1*}, Lal Hruaikima² and Sarada Prasad Pradhan³

¹Emeritus Fellow, Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

²Research Associate, Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

³Associate Professor, Department of Earth Sciences, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand, India

(*Corresponding E-mail: mahendra.singh@ce.iitr.ac.in)

Abstract: Infrastructure development in the Himalayan region frequently requires steep rock cutting, particularly during highway widening and road construction. Although rocks are generally considered strong and capable of supporting heavy loads, Himalayan rock masses are often highly fractured and intersected by numerous joints, making them weak and anisotropic. The stability of these rock slopes largely depends on the orientation, dip, dip direction, and other geological characteristics of the joints. Therefore, proper assessment of rock mass stability is essential before carrying out excavation activities. This lecture highlights the key properties of rock joints that must be identified and mapped during field investigations to evaluate potential slope failures. It also emphasizes the additional instability caused by foundations constructed on slopes. While detailed geotechnical analysis and design are important for ensuring safe excavation, the complex geological conditions, limited time, and financial constraints often make such investigations impractical for every road section. To address these challenges, a simplified rock mass classification approach is proposed to estimate safe cutting heights using basic field observations. Furthermore, practical design charts are developed to assist field engineers in making quick and reliable assessments of slope stability, ultimately supporting safer and more efficient infrastructure development in the Himalayan region.

Keywords: Himalayan region, Rock slope stability, Rock mass classification, Joint orientation, Highway widening, Safe cut height, Geotechnical assessment, Slope failure.

Introduction

The Himalayan region is characterized by complex geological formations, steep slopes, highly fractured rock masses, and active tectonic movements, making infrastructure development particularly challenging. With increasing demands for transportation and connectivity, highway widening and road construction have become essential activities in mountainous areas. These projects often involve extensive rock cutting, which can disturb the natural stability of slopes and increase the risk of landslides and rock failures.

Although rocks are generally considered strong engineering materials, the presence of joints, fractures, and discontinuities significantly influences their strength and stability.

The stability of rock slopes in the Himalaya largely depends on geological factors such as joint orientation, dip, dip direction, spacing, persistence, and surface conditions. These characteristics determine how rock masses respond to excavation and external loading. Improper cutting of slopes without considering these factors can result in serious engineering problems, including rockfalls, sliding failures, infrastructure damage, and threats to human safety. Additionally, the construction of foundations and other structures on slopes introduces additional loads that may further reduce slope stability.

Detailed geological investigations and geotechnical analyses are important for determining safe excavation heights and appropriate slope designs. However, conducting comprehensive investigations for every section of a highway is often difficult due to complex geological conditions, limited financial resources, and time constraints. Therefore, simplified rock mass classification methods and practical design charts can provide valuable alternatives for preliminary field assessments. These approaches allow engineers to evaluate slope stability using easily observable geological characteristics and estimate suitable cutting heights, contributing to safer and more sustainable infrastructure development in the Himalayan region.

Assessment of Safe Cut Height for Highway Rock Slopes

Highway widening in the Himalayan region often requires steep cutting of rock masses. Although rocks are generally considered competent geological materials capable of withstanding heavy loads, Himalayan rock masses are commonly intersected by sets of joints that make them weak and highly

anisotropic. The stability of these slopes depends on the dip and dip direction of the joints, which influence the extent of instability in different slope directions. Therefore, assessing the stability of rock masses before cutting them to the desired height is essential.

Detailed analysis and design are important during highway widening activities. However, the extremely complex geology of the Himalayan region, along with time and financial constraints, makes detailed analysis impractical for every section. As an alternative, a classification approach is suggested to assess safe cut heights using simple field observations. Design charts can also be used by field engineers to simplify calculations and quickly estimate safe cutting heights. This approach provides a practical method for assessing rock slope stability during highway widening activities.

Furthermore, the properties of joints within rock masses need to be carefully observed and mapped in the field to understand their influence on slope instability. The orientation of these joints can cause variations in slope stability, even within the same rock mass. Foundations constructed on slopes may also introduce additional instability, making their assessment important during highway development. By considering joint characteristics, foundation effects, and field-based classification methods, engineers can make more informed decisions regarding the safe height of rock cutting. These considerations are particularly relevant in the Himalayan region, where complex geological conditions make the assessment of cut rock slopes an important part of highway engineering.

Conclusion

Rock slope stability is a major concern in Himalayan infrastructure development, particularly during highway widening and excavation activities. Despite the apparent strength of rocks, the presence of joints, fractures, and geological discontinuities can significantly reduce the overall stability of rock masses. The orientation and characteristics of these joints play an important role in determining potential failure mechanisms and safe cutting heights. Therefore, proper identification and assessment of geological conditions are essential before undertaking excavation work.

Although detailed geotechnical investigations provide more reliable results, they may not always be practical due to geological complexity, time limitations, and financial constraints. In such situations, simplified rock mass classification methods and field-based design charts can serve as useful tools for preliminary stability assessment. These methods help engineers estimate safe excavation heights and identify potentially unstable sections requiring further investigation.

Overall, integrating geological observations with practical engineering assessment methods can improve decision-making, reduce slope failure risks, and support safer infrastructure development in the

Himalayan region. However, simplified approaches should complement rather than replace detailed geotechnical analysis in high-risk or geologically complex areas.