Geotechnical Evaluation of Landslides Along Pathways of Sri Mata Vaishnava Devi Hills, Jammu, India

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1 Introduction

The fragile Himalayan ecosystem, which is characterized by weak rocks, various types of geological discontinuities and unfavorable hydro-geological conditions, is more prone to frequent slope failures especially along the rail and road cut slopes and building terraces (Anbalagan, et.al. 2008). Slope failure phenomenon has increased in Himalayan terrain due to unplanned urbanization, infrastructure projects and other anthropogenic activities. Most of these landslides are triggered by monsoon rainfall. Himalaya is home to the most visited religious places. Either these places are built on extremely rugged terrain or approached by steep terrains. Tourist can reach these places by approach road, which are built on cut-slopes at acute angles. During monsoon period, some cut-slopes become sliding spots. As a result roads are blocked and normal flow of tourists and essentials are disrupted. In view of these consistent slope instability problem in Himalayan region, several authors have suggested different techniques to tackle instability problem. Most of these techniques are probabilistic approach, which mainly shows landslide prone areas on the basis of several inherent causative factors. Some authors have suggested deterministic and numerical methods to analyze slope instability problem. In the present study a detailed slope stability analysis is performed by applying kinematic analysis and back analysis.

Shri Mata Vaishno Devi Shrine is located on a moderately steep hill of Lesser Himalayan terrain on the outer fringes of Katra town in J & K State. It is one of the most famous pilgrimage centres of North India, being visited by thousands of pilgrims every day. Based on previous history of landslide a number of potential landslide prone areas have been identified by the Shrine Board Officials. Pathways are made on steep cut-slopes made up dominantly of limestone rocks. The purpose of the present study was investigation of geological discontinuity responsible for sliding, rock type and slope stability analysis. Two major cut slopes with previous history of landslide were considered in this study.

2 Geological setting

The rocks exposed in and around Vaishnava Devi temple consists of Jammu limestone, which have been brought in juxtaposition with Siwalik Group of rocks on the southern side. The Precambrian Jammu Limestone had been affected by post tectonic activities, leading to formation of a number of geological structures like joints, folds, small scale faults, shear zones and other such structures. This limestone has a special significance as older (Precambrian) limestones are surrounded by younger rocks forming a tectonic structure called inlier (Raha, 1978). It is locally called Riasi inlier.

3 Description of individual landslides

Location – 1

The slide extends for a height of more than 60m with an inclination towards south. The top slopes are steep (>85°) as compared to bottom slopes, which are moderately high (>65°) in nature (Fig. 1). A small retaining wall seen at the bottom provides a temporary toe support. Though the cut slopes are barren due to rock exposures, the top slopes above the cut slope are mostly blanketed by a thin cover of debris, though thick at places. They support sparse to moderate vegetation. A part of the hill slope failed a few months back.

Kinematic analysis: The observed geological discontinuity data have been plotted on a stereonet (Fig. 2). The kinematic analysis of the slope face suggest that the rocks are well traversed by three sets of geological discontinuities namely B, J1 and J2, each being nearly perpendicular to each other. The slope direction being N150°, the joint J1 controls the slope being parallel to it. The bedding and joint J2 acts as release joints. It is basically a plane failure guided mainly by joint J1. From the kinematic analysis, it is seen that the slope dips slightly steeper than the controlling joint of failure J1. The slope is locally steep at many places increasing probability of failure. A few of the apparently unstable rock blocks seen on the slope are close to failure.
Back analysis: This has been used for calculating the shear strength parameters by back analysis by assuming the factor of safety of the slope to be unity. The rock slope, which failed recently, shows a typical planar wedge failure. One of the discontinuities namely joint J1 controls the slope in the area of study. The back analysis was carried out using a computer program, BASP. The program is versatile to carry out the back analysis of the slope, which has a high plane failure possibility and is just stable. Hence, the factor of safety can be assumed to be unity to back calculate the shear strength parameters. The results are given in Table 1. A value of cohesion and angle of internal friction as obtained from the result are, Cohesion – 2.9 t/m$^2$ and Friction angle - 46$^\circ$

Table 1. Results of back analysis

<table>
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<th>CJ</th>
<th>$\varphi$J</th>
<th>$\varphi$R</th>
<th>JRC</th>
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</tbody>
</table>

4 Concluding Remarks:

The Landslide No. 1 has been used for back analysis of rock slope with plane wedge failure using computer program BASP. Since the slope is close to failure, the factor of safety has been assumed to be unity and back calculated the shear strength parameters for joint J1. The values of cohesion and angle of internal friction obtained from the back calculation are 2.9 t/m$^2$ and 46$^\circ$ respectively. These values were used for the analysis of the slopes of Landslide No.2 using computer program SASP. The analysis indicates that the static factor of safety is 1.1 and the dynamic factor of safety is 0.98.

References
