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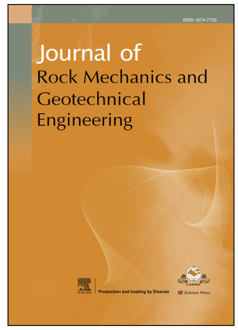

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PII: S1674-7755(17)30173-7

DOI: 10.1016/j.jrmge.2017.09.011

Reference: JRMGE 412

To appear in: *Journal of Rock Mechanics and Geotechnical Engineering*

Received Date: 26 May 2017

Revised Date: 23 September 2017

Accepted Date: 28 September 2017

Please cite this article as: Sah N, Kumar M, Upadhyay R, Dutt S, Hill slope instability of Nainital City, Kumaun Lesser Himalaya, Uttarakhand, India, *Journal of Rock Mechanics and Geotechnical Engineering* (2018), doi: 10.1016/j.jrmge.2017.09.011.

Journal of Rock Mechanics and Geotechnical Engineering

Journal online: www.rockgeotech.org

Hill slope instability of Nainital City, Kumaun Lesser Himalaya, Uttarakhand, India

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Received 25 May 2017; received in revised form 23 September 2017; accepted 28 September 2017

Abstract: Nainital City of Kumaun Lesser Himalaya is prone to mass wasting processes during monsoon season, which mischievously triggers the hill slope instability in this region. Slate, dolomitic limestone, silty sandstone and rhythmite of the Krol Formation are the main rock types. The present study focuses on the investigation of slope stability in the region in terms of potential seismicity and landslide. Geological and geotechnical mapping indicates that the major portion of the area is characterized by slope wash materials and buildings. The combination of 3-4 joint sets with one random joint is the main structure at outcrops. The major geological structures of this area are Nainital lake fault passing from the center of the lake, Main Boundary Thrust at SW, and Khuriya Fault passing from the SE direction of Nainital City. This work finds that different types of discontinuities (e.g. joints and faults), overburden due to unplanned civil structures, and neotectonic activity in the vicinity of this area affect the stability of the city. The slate forms the base of the city, dipping slightly towards the lake side along the NW direction, thus accelerating the instability of this area. Rock mass rating (RMR), slope mass rating, factor of safety (FOS) and graphical analysis of the discontinuity for slope kinematics indicate that the study area is a landslide-prone zone. This study can facilitate reducing the risk of human life, and contribute to the ongoing construction works in the area.

Keywords: hill slope instability; Himalaya region; wedge failure; rock mass rating (RMR); factor of safety (FOS)

1. Introduction

As a major problem in the Himalayan region, landslide is responsible for loss of life and environment degradation (Panikkar and Subramanyan, 1997). Tectonic activities coupled with slope failure give rise to the extensive mass movements in the region (Paul and Mahajan, 1999). In Uttarakhand Himalayan region, several workers have been engaged in landslide investigations, landslide hazards zonation/marking and mitigation, and disaster management for decades. They have documented numerous landslides such as Malpa rock fall in 1998 (Pant and Luirei, 1999), Okhimath landslide in Mandakini valley (Sah and Bist, 1998), Amiya landslide in Kumaun region (Pant and Luirei, 2005), Varunawat landslide in 2003 (Gupta and Bist, 2004), Agastyamuni landslide in 2005 (Rautela and Pande, 2005), slope failure in Alaknanda valley (Joshi and Kumar, 2006) and Asi Ganga landslide in 2012 (Gupta et al., 2013; Martha and Kumar, 2013), which affected the region and caused huge loss of life and property in Uttarakhand.

Nainital City in the Kumaun Himalaya region is very sensitive to slope failure and has suffered numerous slope failures and landslides. Due to the sensitivity to slope failure, many researchers have worked in this region. Hukku et al. (1977), Pande (1974), Anbalagan and Singh (1996) and Puniya et al. (2013) investigated the Rusi village bypass road, Gupta et al. (2016) identified the subsurface tension using the geophysical method in the Rais Hotel. Kumar et al. (2017) carried out the slope stability analysis and geotechnical investigations of Balia-Nala landslide. The present study focuses on the engineering geological mapping, different rock mass classification methods and rock slope kinematics. Different rock mass classification methods and slope kinematics will help in the construction of new buildings in the city.

2. Study area

The investigated area of Nainital City lies between 29°22’15.79’’ and 29°24’16.27’’ north latitude, 79°26’6.05’’ and 79°28’24.82’’ east longitude. Geologically, this region is located in the Outer Lesser Himalaya, bounded by Sher-Ka-Danda ridge to the north-east, Ayarpatta ridge to the south-west and China peaks to the north-west. As shown in Fig. 1, the investigated area lies north to the main boundary thrust (MBT) (Valdiya, 1988) and is dissected by Nainital lake fault (NLF) that passes through the center of Nainital lake (Middlemiss, 1890). Besides aforementioned structures, some branches of NLF also exist in this area. Nainital lake was formed by the rotational movement along the NLF (Valdiya, 1988) ~40-50 thousand years ago (Singhvi et al., 1994). Lithology of the area consists of green and purple slates, dolomitic limestone, silty sandstone and rhythmite, collectively forming Krol Formation (Heim and Gansser, 1939; Fuchs and Sinha, 1974; Pal and Merh, 1974; Valdiya, 1980; Puniya et al., 2013; Kumar et al., 2017). Krol Formation can be further divided into two parts, namely Lower Krol (Korl-A or locally known as Manora slate composed of purple slate and Krol-B or locally known as Hanumangarhi slate composed of grayish to greenish slates) and Upper Krol (Krol-C composed of dolomitic limestone and silty sandstone, Krol-D composed of thickly bedded dolomitic limestone and Krol-E composed of rhythmite and dolomitic limestone).

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