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Assessment of the effectiveness of a rockfall ditch through 3-D probabilistic rockfall simulations and automated image processing

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ABSTRACT

Rockfall ditches or catchment areas aim to collect falling blocks at the toe of a source zone by dissipating the energy of blocks in an excavated trench. The effectiveness of a rockfall ditch is simply expressed by its block catchment performance and can be evaluated by empirically using existing design charts as well as rockfall simulations. Although 2-dimensional (2-D) analysis has been executed to assess the catchment ditch effectiveness in engineering practice, 3-dimensional (3-D) rockfall models have not received enough attention so far. In this study, the effectiveness of a considerably long rockfall ditch to protect a settlement from falling rocks was assessed on the basis of 3-D rockfall analyses executed using high-resolution digital surface models. The rockfall ditch efficiency was found to be moderate to limited for various segments considering the percentage of blocks not trapped by the ditch. Moreover, the sensitivity of ditch efficiency to ditch depth was analyzed by automated image processing method as well. Additionally, a particular section of ditch alignment was fictitiously excavated or filled by synthetic Digital Surface Model (DSM) generation through image processing. 3-D rockfall modeling carried out using the DSMs with synthetically manipulated ditches points out that the effectiveness of a catchment ditch is highly depended upon ditch depth. Even a small volume of block accumulation inside the ditch definitely reduces the ditch performance resulting extended runout distances reaching to residential area. Finally, 3-D rockfall modeling is accepted to be an effective tool to rate the efficiency of existing rockfall ditches and synthetically generated ditches on DSMs (or DEMs) by means of automated image processing method may assist the control of current ditch dimension as well as new catchment ditch design.

1. Introduction

As a fatal geo-hazard, rockfalls threaten settlements and transportation lines located nearby a mountainous terrain (Di Luzio et al., 2020; Zhou et al., 2020). Apart from other rock mass instabilities, rockfalls occur on slope surfaces and many parameters such as lithology, topographic irregularities, type of vegetation, formerly fallen blocks, etc. considerably affect the motion of a falling rock (Volkwein et al., 2011). Therefore, the runout dynamics of rockfall is difficult to predict in terms of source and triggering factors (Asteriou and Tsiambaos, 2016). The hanging blocks on rock slopes, which have remained stable for many years, can suddenly detach and fall (Carla et al., 2019). The most important reason for the sudden failure in rock masses, as opposed to the failures occurring in soils, is that the peak shear strength of discontinuity surfaces can easily reduce to residual shear strength as a result of a few millimeter displacements (Wyllie and Mah, 2002). Moreover, rock blocks falling from steep and high slopes move rapidly on an unpredictable trajectory due to irregularities on terrain.

In engineering practice, a number of engineered and non-engineered rockfall mitigation techniques have been extensively employed to prevent rockfall risk in populated locations (Topal et al., 2007, 2012; Volkwein et al., 2011; Turner and Schuster, 2012; Wyllie, 2015; San et al., 2020). The occurrence and the adverse effects of rockfalls are either eliminated or minimized by engineering solutions in engineered methods whereas non-engineered systems mostly attempt to evade from the collision impact or monitor the motion of probable rockfalls together

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