Geophysical Research Abstracts
Vol. 17, EGU2015-8237, 2015
EGU General Assembly 2015

Predicting Rockfall Occurrence Remotely in an Operational Rail Corridor

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Rockfalls are a type of landslide that are problematic in operation transportation corridors in mountainous environments and adjacent to steep slopes. These frequent and fast acting events often occur suddenly and their occurrence progresses both in space and time. Recent advances in remote sensing approaches, such as terrestrial laser scanning (TLS) and ground based interferometric synthetic aperture radar (Gb InSAR) applications have allowed for the observation of slope behavior at small enough spatial and temporal scales that the prediction of rockfall is now possible. In this study, sequential TLS scanning is used to predict the occurrence of rockfalls in an operational rail corridor in Western Canada where the railway traverses many geomorphologically and geologically complex hazard slopes. Several case studies were analyzed where the focus was on the prediction of rockfall location, size and failure time. In one case, early warning rockfall occurrence was given to the railway prior to rock block release.

In the previous three years, a series of TLS data were collected at several high priority hazard sites traversed by railway infrastructure at intervals ranging from bimonthly to a daily basis. Source zone locations were identified on the basis of small pre-failure deformation. A novel 3-dimensional (3D) model difference filtering approach was used to better detect small pre-failure deformation in complex 3D environments allowing for the identification of source zones from rockfalls as small as 1 m3. A 3D analysis of block rotation and translation was also conducted to better understand failure kinematics and mechanisms. Potential rockfall volumes were projected on the basis of the extent of pre-failure deformation and on the assuming bounding joint structures. In a case of a 2600 m3 rockfall, where daily TLS data were collected prior to failure, two failure time forecasting models were evaluated: Voight's model and the inverse velocity model.

Pre-failure deformation was shown to be a reliable indicator of impending rockfall failure. A pattern of precursory rockfalls and opening of tension cracks was observed in several cases. Pre-failure deformation was detected for block volumes between 1 m3 and 4200 m3 throughout the project area. In one case, pre-failure deformation was detected prior to rockfall failure and advance warning was given to the railway. For this case, projected rockfall volume was also accurate within an order of magnitude. For the 2600 m3 rockfall event, the failure forecast time was accurate within an order of magnitude of failure time for both Voight's model and the inverse velocity method; the latter offering the advantage of its simpler application not requiring a non-linear regression analysis. In this study we have shown that with the application of remote sensing on hazardous slopes a prediction of rockfall occurrence is possible and early warning can be provided.