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Rock Slide Risk Assessment: A Semi-Quantitative Approach

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Rock slides can be better managed by systematic risk assessments. Any risk assessment methodology for rock slides involves identification of rock slide risk components, which are hazard, elements at risk and vulnerability. For a quantitative/semi-quantitative risk assessment for rock slides, a mathematical value the risk has to be computed and evaluated. The quantitative evaluation of risk for rock slides enables comparison of the computed risk with the risk of other natural and/or human-made hazards and providing better decision support and easier communication for the decision makers. A quantitative/semi-quantitative risk assessment procedure involves: Danger Identification, Hazard Assessment, Elements at Risk Identification, Vulnerability Assessment, Risk computation, Risk Evaluation. On the other hand, the steps of this procedure require adaptation of existing or development of new implementation methods depending on the type of landslide, data availability, investigation scale and nature of consequences. In study, a generic semi-quantitative risk assessment (SQRA) procedure for rock slides is proposed. The procedure has five consecutive stages: Data collection and analyses, hazard assessment, analyses of elements at risk and vulnerability and risk assessment.

The implementation of the procedure for a single rock slide case is illustrated for a rock slope in Norway. Rock slides from mountain Ramnefjell to lake Loen are considered to be one of the major geohazards in Norway. Lake Loen is located in the inner part of Nordfjord in Western Norway. Ramnefjell Mountain is heavily jointed leading to formation of vertical rock slices with height between 400-450 m and width between 7-10 m. These slices threaten the settlements around Loen Valley and tourists visiting the fjord during summer season, as the released slides have potential of creating tsunami. In the past, several rock slides had been recorded from the Mountain Ramnefjell between 1905 and 1950. Among them, four of the slides caused formation of tsunami waves which washed up to 74 m above the lake level. Two of the slides resulted in many fatalities in the inner part of the Loen Valley as well as great damages. There are three predominant joint structures in Ramnefjell Mountain, which controls failure and the geometry of the slides. The first joint set is a foliation plane striking northeast-southwest and dipping 35˚-40˚ to the east-southeast. The second and the third joint sets are almost perpendicular and parallel to the mountain side and scarp, respectively. These three joint sets form slices of rock columns with width ranging between 7-10 m and height of 400-450 m. It is stated that the joints in set II are opened between 1-2 m, which may bring about collection of water during heavy rainfall or snow melt causing the slices to be pressed out. It is estimated that water in the vertical joints both reduces the shear strength of sliding plane and causes reduction of normal stress on the sliding plane due to formation of uplift force. Hence rock slides in Ramnefjell mountain occur in plane failure mode.

The quantitative evaluation of rock slide risk requires probabilistic analysis of rock slope stability and identification of consequences if the rock slide occurs. In this study failure probability of a rock slice is evaluated by first-order reliability method (FORM). Then in order to use the calculated probability of failure value (P_f) in risk analyses, it is required to associate this P_f with frequency based probabilities (i.eP_f / year) since the computed failure probabilities is a measure of hazard and not a measure of risk unless they are associated with the consequences of the failure. This can be done by either considering the time dependent behavior of the basic variables in the probabilistic models or associating the computed P_f with frequency of the failures in the region. In this study, the frequency of previous rock slides in the previous century in Remnefjell is used for evaluation of frequency based probability to be used in risk assessment. The major consequence of a rock slide is generation of a tsunami in the lake Loen, causing inundation of residential areas around the lake. Risk is assessed by adapting damage probability matrix approach, which is originally developed for risk assessment for buildings in case of earthquake.