Geophysical Research Abstracts
Vol. 18, EGU2016-12875, 2016
EGU General Assembly 2016

Rock slope instabilities in Norway: First systematic hazard and risk classification of 22 unstable rock slopes

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Unstable rock slopes that can cause large failures of the rock-avalanche type have been mapped in Norway for almost two decades. Four sites have earlier been characterized as high-risk objects based on expertise of few researchers. This resulted in installing continuous monitoring systems and set-up of an early-warning system for those four sites. Other unstable rock slopes have not been ranked related to their hazard or risk. There are ca. 300 other sites known of which 70 sites were installed for periodic deformation measurements using multiple techniques (Global Navigation Satellite Systems, extensometers, measurement bolts, and others). In 2012 a systematic hazard and risk classification system for unstable rock slopes was established in Norway and the mapping approach adapted to that in 2013.

Now, the first 22 sites were classified for hazard, consequences and risk using this classification system. The selection of the first group of sites to be classified was based on an assumed high hazard or risk and importance given to the sites by Norwegian media and the public. Nine of the classified 22 unstable rock slopes are large sites that deform inhomogeneously or are strongly broken up in individual blocks. This suggests that different failure scenarios are possible that need to be analyzed individually. A total of 35 failure scenarios for those nine unstable rock slopes were considered.

The hazard analyses were based on 9 geological parameters defined in the classification system. The classification system will be presented based on the Gamanjunni unstable rock slope. This slope has a well developed back scarp that exposes 150 m preceding displacement. The lateral limits of the unstable slope are clearly visible in the morphology and InSAR displacement data. There have been no single structures observed that allow sliding kinematically. The lower extend of the displacing rock mass is clearly defined in InSAR data and by a zone of higher rock fall activity. Yearly average displacement rates of up to 6 cm are measured with differential GNSS and InSAR. Cosmogenic nuclide dating suggests an acceleration of the present displacement compared to the average displacement since the initiation of the gravitational movement approximately 7000 years ago. Furthermore, there exists a pre-historic rock avalanche 3 km north along the same slope. These characteristics result in a very high hazard for the Gamanjunni unstable rock slope.

The consequence analyses focus on the possibility of life loss only. For this the number of persons in the area that can be affected by either the rock slope failure itself and/or its secondary consequence of a displacement wave in case that a rock slope failure would hit a water body is estimated. For Gamanjunni the direct consequences are approximately 40 casualties, representing medium consequences.

A total of 48 scenarios were finally analyzed for hazard, consequences and risk. The results are plotted in a risk matrix with 5 hazard and 5 consequence classes, leading to 4 risk classes. One unstable rock slope was classified as very high hazard, 9 scenarios as high hazard, 25 as medium hazard and 13 as low hazard, while none were classified as very low hazard. The consequence analyses for those scenarios resulted in 5 scenarios with very high consequences (>1000 potential casualties), 13 scenarios with high consequences (100-1000 casualties), 9 scenarios with medium consequences (10-100 casualties), 6 scenarios with low consequences (1-10 casualties) and 15 scenarios with very low consequences (0-1 casualties). This resulted in a high risk for 6 scenarios, medium to high risk for 16 scenarios, medium risk for 7 scenarios and low risk for 19 scenarios. These results allow determining which unstable rock slopes do not require further follow-up and on which further investigations and/or mitigation measures should be considered.