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Probabilistic Rockfall Hazard Analysis

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Rockfall hazard analysis requires the assessment of both the onset probability and the reach probability. In the literature, these two probabilities have always been assessed separately and then combined. This approach does not allow to characterize correctly the reach probability as both rockfall "magnitude" (e.g., block volume) and runout "intensity" (e.g., kinetic energy) are needed for a rigorous hazard and risk assessment. In order to fill this gap, we propose a Probabilistic Rockfall Hazard Analysis (PRHA) methodology allowing for the computation of rockfall hazard curves that express the exceedance probability for a given location of being involved in a rockfall event with a specific level of kinetic energy, integrating the contribution of different volume scenarios. The approach has been adapted from Probabilistic Seismic Hazard Analysis (PSHA) (Cornell, 1968), and consists of four steps: (1) identification of rockfall source areas, (2) modelling of onset probability (in terms of annual frequency), (3) modelling of rockfall runout and spatially-varying kinetic energy, (4) probabilistic analysis.

Onset probability is modelled, for each area with different onset susceptibility, through a frequency-magnitude relationship, derived from historical event rockfall catalogues analogously to the Gutenberg-Richter approach in seismology.

Rockfall runout of non interacting blocks is simulated by means of the 3D modelling code HY-STONE (Crosta et al, 2004; Frattini et al, 2008; Agliardi et al, 2009). Modelling results have been obtained for different real-world settings (i.e. different slope morphology, initial free fall, vegetation, countermeasures). These results suggest that the kinetic energy for all blocks passing through each model cell is log-normally distributed. This makes possible to completely describe the distribution of energy by the first two moments statistics (i.e. mean and standard deviation). These statistics are analogous to the values predicted by attenuation relationships in seismic analysis, with the rockfall kinetic energy being analogous to the seismic ground motion.

The probabilistic analysis integrates over all rockfall volume scenarios and estimates the probability of exceeding values of kinetic energy, at each site, within a reference time interval. This function is referred to as the "rockfall hazard curve". This curve can be used for a more rigorous quantitative probabilistic risk analysis to help in land planning and zonation, as well as for countermeasure design and verification (e.g. cost/benefit and cost/efficiency analysis).

To produce a rockfall hazard map it is necessary to further reduce a hazard curve to a single value. This can be done by choosing a fixed probability of exceedance (e.g., 0.1) in a certain time interval (e.g., 50 years) following standards or regulation requirements.

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