# Improved methodology for rock fall hazard zoning at the local scale

## ABSTRACT

Rock falls represent a serious threat to communities living in mountainous areas in several European countries, and their potential hazard must be taken into account for an appropriate land use planning and for establishing risk mitigation measures. Rock fall hazard assessment and zoning at the local (and site specific) scale(s) require detailed information on rock fall frequency of departure and trajectories, which have to be determined quantitatively.

The research work performed in this Thesis deals with procedures for rock fall hazard zoning for urban planning at the local scale, particularly focusing on methodologies based on rock fall trajectory modelling.

This objective was pursued in the first part of the work by comparing current methodologies used in Europe, based on 2D rock fall modelling, for achieving a clearer understanding of differences, weak points and limits characterising each procedure. The results of the several performed sensitivity analyses show that rock fall hazard assessment and zoning are highly conditioned by both national guidelines and mapping methodologies. These results underline as well that, as a consequence of diversities in guidelines and due to assumptions/uncertainties in zoning techniques, land use planning measures at a given site do change considerably, depending on which methodology and respective guidelines are applied. In particular, significant differences arise both in terms of extent of the hazard zones, and in terms of type of land use planning. Measures for urban planning correspond indeed to definitions of hazard degrees changing from one country to another, according to the adopted risk management strategies, which condition the regulations for the areas in danger and therefore the choice of threshold values for energy and frequency.

The purpose of the second part of the work was to propose improvements to quantitative rock fall hazard zoning at the local scale, based on the Cadanav methodology developed at the Rock Mechanics Laboratory of EPFL. In particular, the new methodology attempts at reducing assumptions and uncertainties affecting the use of trajectory modelling results and the techniques for combining energy and rock fall frequency according to an intensity-frequency diagram. The new Cadanav methodology evaluates the hazard degree by means of “hazard curves”. The curves are described at each point of the slope by energy-return period couples, to be superposed to an intensity frequency diagram in order to determine which hazardous condition prevails at that point of the slope. The new methodology allows for hazard zoning obtained starting from either 2D or 3D trajectory modelling. For 2D modelling-based zoning, it was checked by means of comparisons with the original version of the Cadanav methodology, performing sensitivity analyses for several sites, block sizes and return period conditions. For 3D modelling-based zoning, the methodology was validated by studying benchmark problems for an infinite linear cliff topography, and tested as well on a more realistic complex topography. For these two configurations, the analyses were performed for several return period values and types of scenario, i.e. single rock fall hazard instabilities, either localised or diffused, and combined instabilities, characterised by different frequencies of failure, but same block size. In addition, further elements to be accounted for in rock fall hazard zoning were discussed, such as the influence of the block size on hazard zoning and the combination of several rock fall hazards affecting the same site, but characterised by different block sizes and failure frequencies.

In terms of results, the new methodology performs well in all the tested conditions and provides a more objective and detailed hazard evaluation. Its implementation is general and flexible, as it can be used based both on 2D and on 3D trajectory modelling as well as according to different intensity-frequency diagrams (e.g. Switzerland, Principality of Andorra), and it allows for evaluating the rock fall hazard for complex scenarios involving several sources and event return periods.

**Keywords**: rock fall, trajectory modelling, hazard assessment, hazard zoning methodology, hazard zoning guidelines, land use planning.

## Publications


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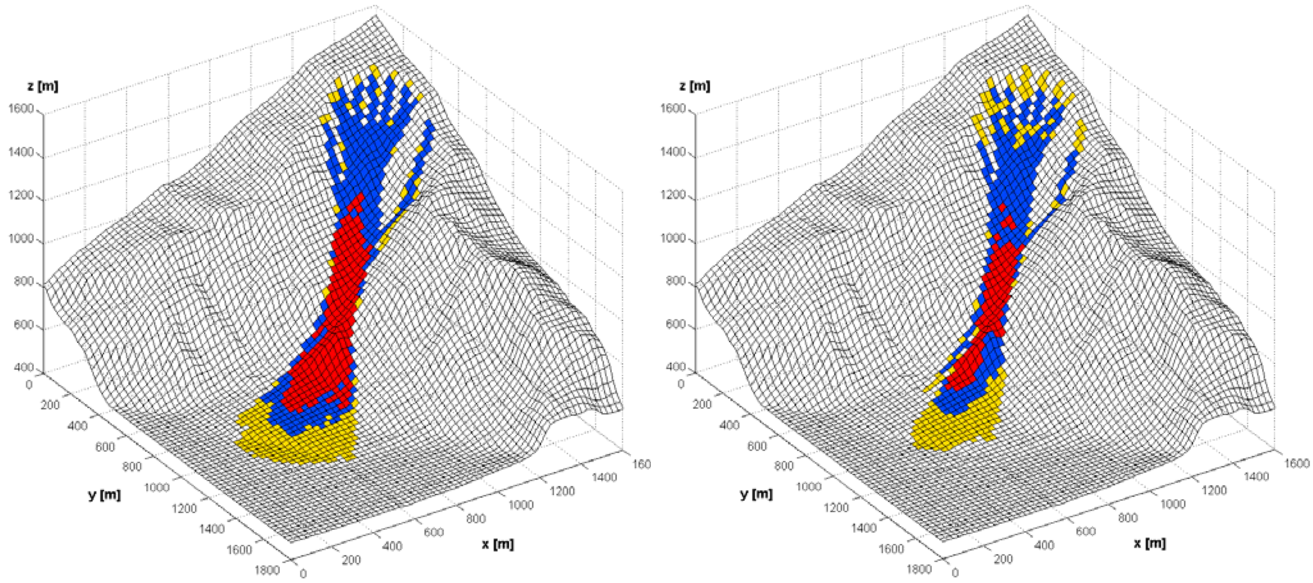


*Example of hazard zoning for a complex topography and for a source area constituted by 9 cells.*
*The comparison of the left and right figures shows the influence on hazard zoning of a change in the return period of the events, i.e. 1 block released from each cell on average every 50 years (left) and 100 years (right).*