A Novel Approach to Assess the Ability of a Protection Barrier to Mitigate Rockfall Hazard

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INTRODUCTION

Various types of rockfall protections can be used to intercept falling blocks such as barriers, nets and dams. There is a growing interest to fully consider the effect of these protection structures in rockfall trajectory simulation tools. Thus, there is a strong need for developing tools and methods that can integrate the protective effect of these structures in both rockfall trajectory simulations and risk assessment methods.

In practice the design of a barrier for a given site is done by comparing a statistical descriptor of the block kinematic energy and the barrier reference capacity. The barrier reference capacity could be calculated following the European guideline (ETAG 027: Guideline for European Technical Approval of falling Rock Protection Kits (2013)). However this method of design does not account for the different types of loading induced by the block kinematic parameters (translational velocity, rotational velocity, impact angle, impact position) which can lead to the design of a barrier inefficient to stop the blocks. Quantifying the response of the barrier for different loading conditions requires complex and time consuming modelling approaches (Finite Element Method (FEM) or Discrete Element Method (DEM)) which cannot be directly coupled with classical rockfall trajectory analysis models. To overcome this problem, meta-models which can mimic the behaviour of complex models with reduced computational time can be built.

This study is dedicated to the development and the evaluation of a new approach to integrate variable and realistic impact loading conditions into the assessment of the barrier efficacy. It considers a low-energy barrier for which a FEM model is available. First, a meta-model is created based on the FEM model simulation results, considering input parameters relevant to realistic impact conditions. Then, the meta-model is used to evaluate the effectiveness of the barrier in stopping blocks for two real rockfall scenarios. Finally, the advantages and limitations of this approach are discussed and compared to current practice in protection structure design.

BARRIER

The study addresses the response of a low-energy barrier which is widely spread in the Italian Alps. The model was calibrated using results from experimental studies. The barrier is made of steel post fixed at its base, transverse cables evenly spaced and a hexagonal mesh-work (**Fig. 1**). Side cables connect the outer most post to the ground. The barrier is 3.2 m in height and has 15 evenly spaced longitudinal cables of 12 mm diameter. Side cables were 18 mm. Three spans are considered, with a 5m inter-posts spacing.

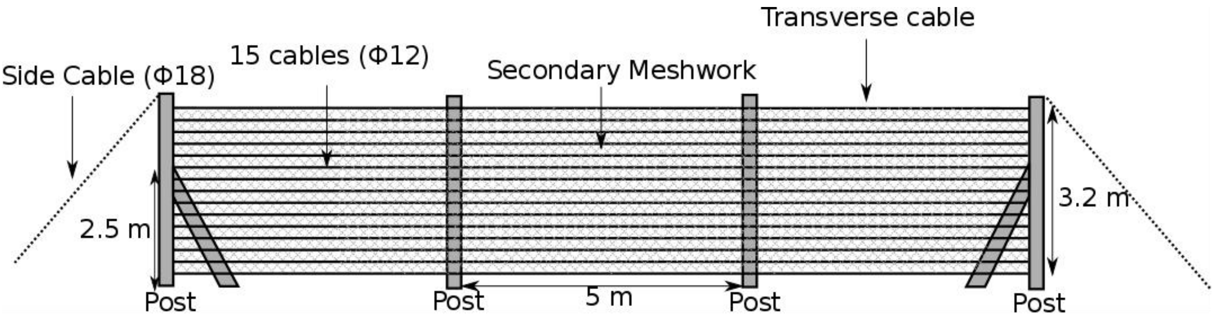

Fig. 1: Schematic representation of the barrier.

COUPLING A META-MODEL AND A ROCKFALL MODEL

Based on the FEM model, a meta-model which can predict the success or the failure of the barrier to stop the block is created using Support Vector Machine (SVM). 6 input parameters related to the block trajectory are considered to build the meta-model: the block translational velocity, the block rotational velocity, the block volume, the block impact position along the horizontal and vertical axis, the incidence impact angle. The meta-model is created using 300 simulations of the FEM model. The 300 combinations of the input parameters were generated with a Latin Hypercube sampling assuming uniform distributions for each input parameter.

The accuracy of barrier design is evaluated for two rockfall scenarios using the meta-model and the reference capacity of the barriere. The rockfall site is located in the 'Forêt communal de Vaujany' in the French Alps. The scenarios focus on protecting a forest road located on the slope (38°) from cubic blocks (volume: 0.1 to 1 m^3). Rockfall simulations were conducted using a 3D rockfall model. The two rockfall scenarios were selected to test the influence of two different loading conditions on the barrier efficacy.

CONCLUSION

The current design practices are mainly based on the barrier reference capacity. In this study, the reference capacity of the barrier was considered as a value obtained from impacts following the recommendations of the European guideline. A straightforward design for the type of barrier used in this study would consider that all the block having a kinetic energy less than 200 kJ are stopped. However, it was shown from FEM simulations that barrier failures occur below the 200 kJ limit. These behaviors appear to be dependent on the impact conditions. Analysis of the data also showed that, although some trends could be observed, there is no a simple correlation between input parameters and block-barrier interaction mechanisms. These results bring to light the shortcomings of deterministic barrier design approaches based on a single impact assessment test. To accommodated this limitation a probabilistic approaches to predict the barrier response as a function of the impact conditions is developed. The meta-model and the reference capacity of the barriere were used to predict the barrier response for two rockfall scenarios. The results show that current practice is far too optimistic with respect to the barrier ability in stopping the blocks. This demonstrates the benefit in using the meta-model for design or hazard assessment purpose.

Keywords: rockfall, protection barriers, meta-model, FEM