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Mount Farinaccio rockfall: comparision between kinematic simulations and experimental field tests

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ABSTRACT

Analisi del moto di caduta massi al Sasso Farinaccio (SO): confronto tra simulazioni cinematiche e sperimentazioni in sito

I fenomeni di caduta massi sono frequenti nelle aree alpine e, per mitigare i rischi che creano alla popolazione ed agli insediamenti umani, è indispensabile una corretta previsione delle possibili traiettorie e dei parametri cinematici del moto che i blocchi in incipienza di movimento assumerebbero qualora si staccassero dalla parete.

Il presente contributo riguarda lo studio dettagliato del moto di caduta massi e della sua propagazione, ottenuto grazie alla realizzazione di prove sperimentali effettuate in Val Grosina (SO). I risultati della sperimentazione sono stati paragonati con quelli provenienti da simulazioni cinematiche precedentemente effettuate nell'area d'indagine, utilizzando differenti metodi, sia bidimensionali sia tridimensionali. In una prima serie di simulazioni i dati di input caratterizzanti il moto dei blocchi sono stati ipotizzati sulla base dei valori bibliografici, ottenuti in contesti geologici e geomorfologici simili a quello di indagine, mentre in una seconda serie tali valori sono stati stimati basandosi sulla posizione di arresto di alcuni blocchi crollati nell'area di studio nel 2010. Il confronto dei risultati ottenuti utilizzando i diversi approcci con quelli sperimentali, mostra che, per ottenere previsioni affidabili delle traiettorie dei blocchi e quindi mappe di pericolosità attendibili, è necessario effettuare un'accurata calibrazione dei parametri che caratterizzano il moto di caduta.

KEY WORDS: *back-analysis, in situ test, kinematic simulations, rockfall, Sasso Farinaccio (SO).*

Rockfalls are very common and dangerous in all mountain areas, because of velocities of their motion which render any warning equipments useless. A reliable forecast of trajectories, velocities, height bounces and kinetic energies of moving blocks is fundamental in the establishment of hazard maps and so in territory management.

This research deals with the prediction of kinematic parameters, in particular the restitution coefficients (BOZZOLO & PAMINI, 1986; PITEAU & CLAYTON, 1987; HOEK & BRAY, 1988), which control the motion of falling blocks. A detailed study of rockfall motion was carried out through in situ tests and numerical simulations applied to a site located in Valtellina (SO). Initially a classical approach, using kinematical simulations, both bi-dimensional and three-dimensional, was adopted. Afterwards the results of kinematic simulations were compared which those obtained from in situ tests.

Experimental rockfall tests were performed in a scree slope located on the left hydrographical side of the Western Grosina Valley (SO), which a traverse of Valtellina. The geological context is related to the Superior Austro-alpine domain and the outcropping rocks pertain to the Grosina Valley Formation, which consists mainly in Storile Mount paragneiss and micaschists.

The area of interest may be divided in a source area, which is a rock cliff with a mean slope gradient of 55°, and a transition and accumulation zone, which is characterized by a mean slope gradient of 35°. The former is a denudation niche, high about 70metres; its state of activity is witnessed by numerous fallen blocks located along the underlying slope. The latter is characterized by a fining-upward scree cone, which starts from the bottom of the cliff and, after two road crossings, reaches the Roasco River, at the valley floor. This talus cone, with absence of trees, except seedlings of larch and spruce in the lower part of the slope, forms a preferential corridor for the blocks which fall down along the slope and reach the streets and sometimes also the Roasco River, as happened in autumn 2010. This rockfall event involved numerous blocks, which reached the roads and damaged them.

A detailed geo-mechanical survey carried out in the source area, allowed to recognize the rock volume prone to failure or to fall and to individuate the kinematic of block detachment and so the triggering modality of rockfalls, which resulted related to toppling and sliding of wedges.

The kinematic simulation of the block in precarious equilibrium were performed, using as the initial motion condition the results inferred by the geo-mechanical survey. Afterwards the motion, which is dominated by rebounds, is described using the so called "restitution coefficients", which include normal restitution coefficient and

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tangential one. These parameters are expressed by the ratio between the velocity after and before the impact, respectively normal and tangential to the slope, therefore they quantify the loss of energy which occurs during impact. Neither direct field procedures nor empirical correlations are available to estimate the local restitution coefficients, which have been derived by many author performing in situ rockfall tests. As usually done, in the first sets of simulations the mean of bibliographic values (AZZONI *et alii*, 1986; HOEK, 1987; PITEAU & CLAYTON, 1987; HOEK & BRAY, 1988; CLERICI *et alii*, 2004; GIANI *et alii*, 2004; FERRARI *et alii*, 2011), obtained in similar geological and geo-morphological contexts, was used. Afterwards the calculated values were calibrated using a back-analysis approach, based on the stopping points of the blocks fell down in the study area in 2010.

Kinematic simulations were performed using two different common rebound modelling approaches: the former method uses the lumped mass approach to model the block as a single material point, in a three-dimensional grid, while the latter utilises the rigid body approach which account for the block shape, using a two-dimensional section.

The stopping points of blocks obtained using bibliographic values are located farther than those derived from the back-analysis process. The results of both simulation approaches were compared with in situ tests, which were performed on May 2010. During the experimental tests some coloured blocks, with different size and shape, were thrown down the slope by a caterpillar. The blocks were painted using different colours to allowed their recognition. The trajectory of every block was recorder using both lateral fixed cameras and a frontal mobile one. The frame by frame analysis of videos, and in particular of the barycentre displacements of moving blocks, allowed to individuate the rebound as the predominant kind of motion and to calculate, for each impact, the velocities and dynamics parameters of falling blocks, such as energies, heights of bounce, restitution coefficients, impact and limit angles.

The analysis of the movie results suggests that, even if the trajectories of blocks cross a talus cone which can be described as an homogeneous lithotecnical unit, the assumption of constant restitution coefficients is not validated by the image analyses. Therefore it seems that the restitution coefficients depend not only on the slope characteristics, but also on the physical properties of block and on its kinematic condition before the impact. It follows that the simplification imposed by numerical simulations may be excessive in relation to the complexity of the rockfall process.

The comparison among the stopping points of in situ tests and those of simulations showed that, to obtain reliable results from kinematical models, it is at least necessary an accurate calibration process of motion parameters, which can be performed using the back-calculation of a past rockfall event occurred in the study area. In the present study the use of literature data, although selected from a morphological and lithological context similar to investigated area, supplies a big overestimation of motion parameters and so of: path lengths, energies and bounce heights reached by falling blocks, with a subsequent over sizing of protection measures, conversely the back-analysis performed on the 2010 rockfall event gives a good accordance between experimental tests and simulation results. A calibration process by back analysis is therefore recommended to define reliable hazard scenarios and design adequate protections measures.

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