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Characterisation of rockfalls from seismic signal: insights from laboratory experiments

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Rockfalls, debris flows and rock avalanches represent a major natural hazard for the population in mountainous, volcanic and coastal areas but their direct observation on the field is very difficult. Recent field studies showed that gravitational instabilities can be detected, localized and characterized thanks to the seismic signal they generate. Therefore, a burning challenge for risks assessment related to these events is to obtain quantiative informations on the characteristics of the rockfalls (mass, speed, extension,...) from the properties of the signal (seismic energy, frequencies,...).

Using a theoretical model of viscoelastic impact of a sphere on a plane, we develop analytical scaling laws relating the energy radiated in elastic waves, the energy dissipated in viscoelasticity during the impact and the frequencies of the generated seismic signal to the mass m and the impact speed V_z of the sphere and to the elastic parameters of the involved materials. The radiated elastic energy is shown to vary as $m^{5/3}V_z^{11/5}$ on plates and as $mV_z^{13/5}$ on blocks, regardless of the elastic parameters. The energy dissipated in viscoelasticity does not depend on the support thickness and varies as $m^{2/3}V_z^{11/5}$. The mean frequency of the generated signal is inversely proportional to the impact duration.

Then, we conduct simple laboratory experiments that consist in dropping spherical beads of different size and materials and small gravels on thin plates of glass and PMMA and rock blocks. In the experiments, piezoelectric accelerometers are used to record the signals in a wide frequency range: 1 Hz to 56 kHz. The experiments are also monitored optically using fast cameras. The elastic energy emitted by an impact on the supports is first quantitatively estimated and compared to the potential energy of fall and to the potential energy change during the shock. We observe a quantitative agreement between experimental data and the analytical scaling laws, even when we use small gravels instead of spherical beads as impactors. These experiments allows to valid the theoretical model and to establish the energy budget of an impact. The established scaling laws are also tested for real scale experiments of boulders impacts conducted in Tahiti, French Polynesia.

Empirical scaling laws are finally established to relate the dynamics and the initial parameters (mass, aspect ratio i.e., height over length, and bead diameter) of granular flows with the metrics of the generated seismic signal.