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# Velocity-dependent shear resistance of soils, rocks, and bi-material interfaces at landslide stress levels

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The resistance of the deforming material plays a fundamental role in the initiation, reactivation, and kinematics of landslides. It is controlled by various parameters, including the mineral composition of the soil or rock and its structure, the pressure and chemistry of the pore fluid, the temperature, and the deformation rate at which the movement occurs. Depending on the material characteristics and layering, shearing may be localised within a soil mass, between rock surfaces, or at the interface between soil and rock. Various studies showed that catastrophic failure of a reactivated landslide might not occur in materials exhibiting velocity-strengthening behaviour. On the contrary, velocity-weakening (of various possible natures) was related to dramatic accelerations and catastrophic failures. However, the subject remains controversial, primarily due to the difficulties in relating, quantitatively, laboratory-scale results with observed field behaviours, and to a lack of consensus over a unified framework to describe the behaviour of different types of landslides across the entire range of velocities.
Here we present the results of laboratory experiments in which we shear samples of a clayey soil, of the clay-bearing rock from which the soil derives, and of various other rocks under stress levels typical of landslide shear zones. Additionally, we perform shear tests on the bi-material interface of soil-rock samples, using shear zone materials of active or recent landslides. Our experiments show that the behaviours of the various assemblies, when sheared at different velocities, are different, and that the velocity-dependent behaviour is also affected by the stress state and stress history.
By comparing results obtained with ring-shear and rotary-shear tests across a wide range of velocities, we suggest that several landslide materials could exhibit an important resistance instability in the rapid to very-rapid velocity range, with potential for catastrophic failure, and that the laboratory-scale results support proposed single frameworks for characterising both slow-sliding and catastrophic failure of landslides. Finally, we show that by taking the velocity-dependent behaviour into account, more reliable stress-state thresholds for landslide early warning can be defined, and the landslides creep behaviour can be better interpreted.